

Q $\Rightarrow$ Find speed of surface molecule

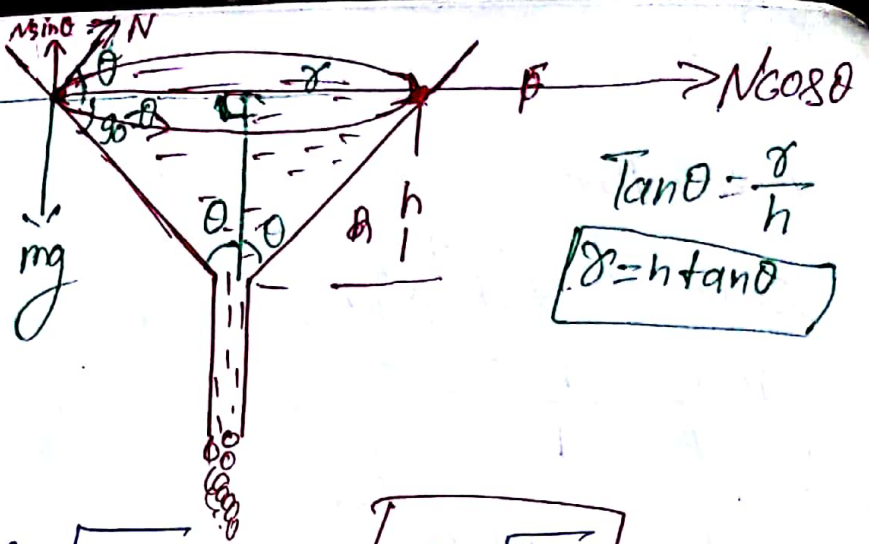
$$N \cos \theta = m r \omega^2$$

$$\frac{N \cos \theta}{N \sin \theta} = \frac{m r \omega^2}{m g}$$

$$\cot \theta = \frac{v^2}{r g}$$

$$v = \sqrt{r g \cot \theta}$$

$$v = \sqrt{g h} \quad \text{Ans}$$



$$\tan \theta = \frac{r}{h}$$

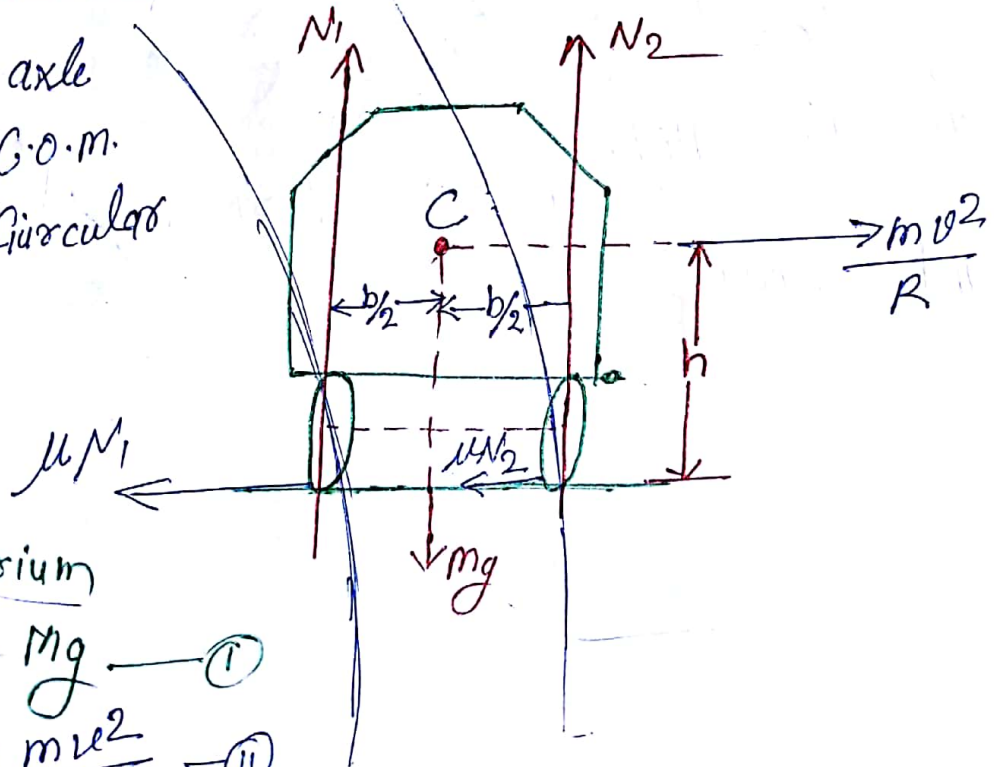
$$r = h \tan \theta$$

Overturning Speed $\Rightarrow$

$b \rightarrow$ length of axle

$h \rightarrow$ position of C.O.M.

$R \rightarrow$ Radius of Circular Track.



For Equilibrium

$$N_1 + N_2 = M g \quad \text{--- (i)}$$

$$\mu(N_1 + N_2) = \frac{m v^2}{R} \quad \text{--- (ii)}$$

$$\tau_{\text{net about C.O.M.}} = 0 \quad \mu N_2 h + \mu N_1 h + N_1 \left(\frac{b}{2}\right) - N_2 \left(\frac{b}{2}\right) = 0$$

$$\mu(N_1 + N_2)h = (N_2 - N_1) \frac{b}{2}$$

$$\left(\frac{m v^2}{R}\right) \frac{2h}{b} = N_2 - N_1 \quad \text{--- (iii)}$$

(i) & (iii)

$$N_2 = \frac{m g}{2} + \frac{m v^2}{R} \left(\frac{h}{b}\right)$$

$$N_1 = \frac{m g}{2} - \frac{m v^2}{R} \left(\frac{h}{b}\right)$$

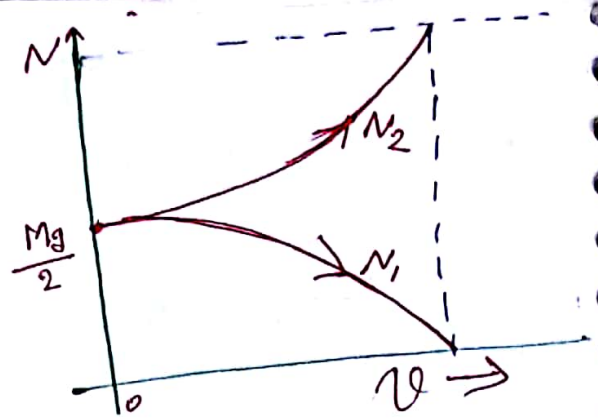
Graph $\Rightarrow$

Overturning speed

Speed at which N_1 become Zero

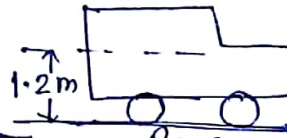
$$\frac{mv_0^2}{R} \left(\frac{h}{b} \right) - \frac{mg}{2} = 0$$

$$v_0 = \sqrt{\frac{bRg}{2h}}$$



Q $\Rightarrow$

Overturning speed.



$$v_0 = \sqrt{\frac{bRg}{2h}} \Rightarrow \sqrt{\frac{1.6 \times 80 \times 10}{2 \times 1.2}} \quad b = 1.6 \text{ m}$$

for $v_0 \rightarrow$ High.

$h \rightarrow \text{min} \quad b \rightarrow \text{Max.}$

$$\Rightarrow \sqrt{\frac{1.6 \times 80}{1.2}} \Rightarrow 80 \sqrt{\frac{10}{12}}$$

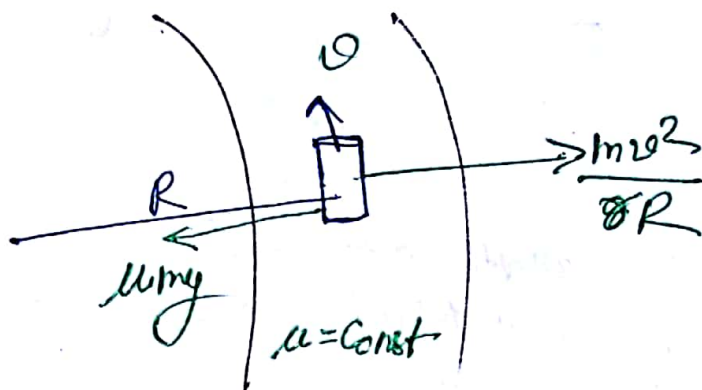
Banked Road $\Rightarrow$

Q2 // ~~max~~
Max speed of Car

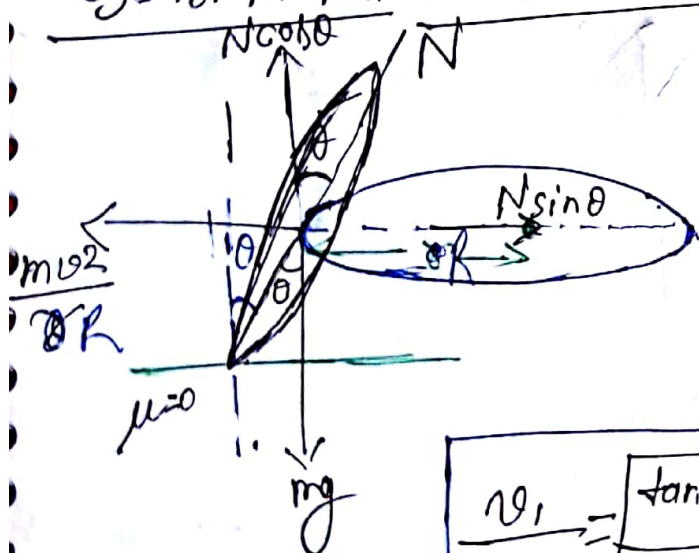
$$v_{max} = \sqrt{\mu R g}$$

$$v \leq \sqrt{\mu R g}$$

$$\mu \rightarrow 0 \quad v = 0$$



Cyclist in Horizontal Frictionless Circular track $\Rightarrow$



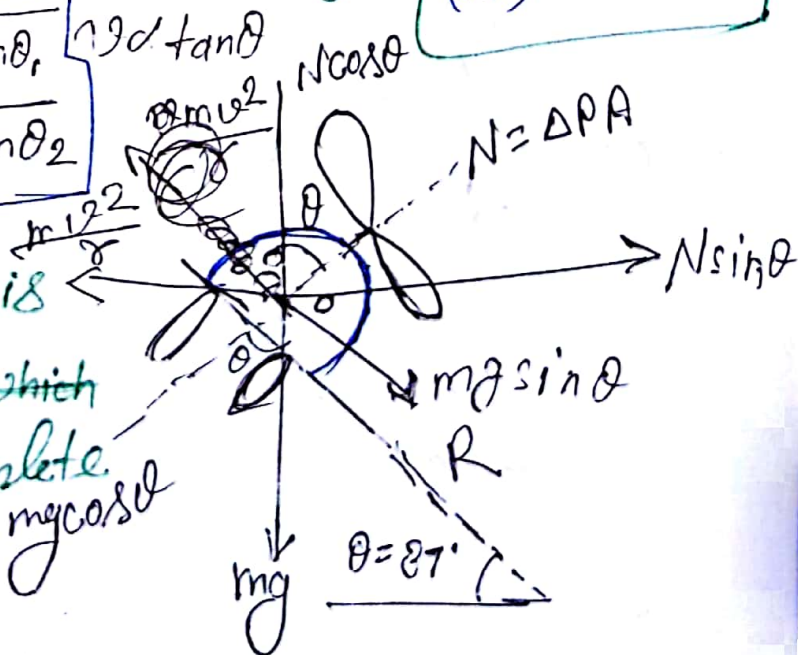
$$\frac{N \sin \theta}{N \cos \theta} = \frac{mv^2/R}{mg}$$

$$\tan \theta = \frac{v^2}{Rg}$$

$$v = \sqrt{Rg \tan \theta}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{\tan \theta_1}{\tan \theta_2}}$$

Q3 // If speed of plane is 540 km/hr then find in which time in which it complete one cycle.



$$\frac{mv^2}{R} = mg \sin \theta$$

$$v^2 = Rg \sin \theta$$

$$\frac{mv^2}{R} = N \sin \theta$$

$$mg = N \cos \theta$$

$$\tan \theta = \frac{v^2}{rg}$$

$$\tan \theta = \frac{R^2 \omega^2}{Rg} \Rightarrow \tan \theta = R\omega \cdot \frac{\omega}{g}$$

$$\tan \theta = \frac{v}{g} \omega$$

$$\omega = \frac{g \tan \theta}{v}$$

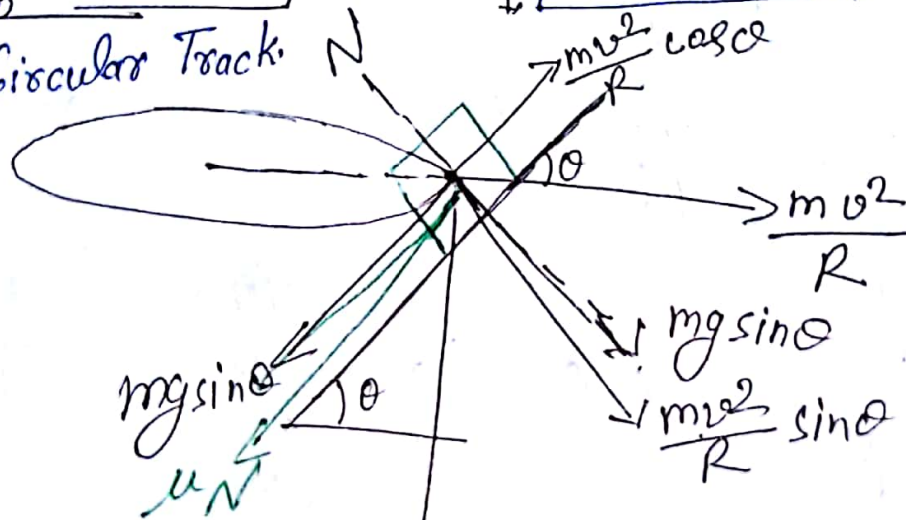
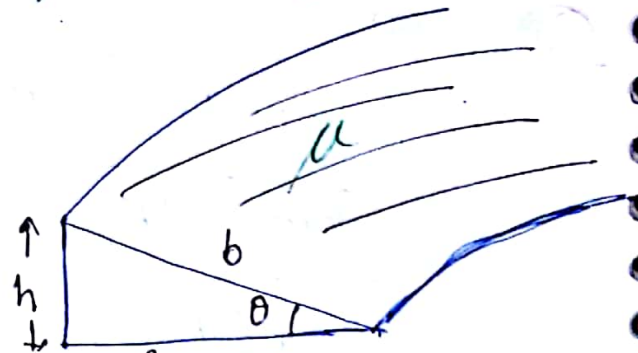
$$\frac{2\pi}{T} = \frac{g \tan \theta}{v}$$

$$T = \frac{2\pi v}{g \tan \theta}$$

$b \rightarrow$ width of road
 $h \rightarrow$ Altitude $\theta \rightarrow$ small.

$$\tan \theta \approx \frac{h}{b} \approx \sin \theta$$

$R \rightarrow$ Radius of Circular Track.



For v_{max}

$$\frac{mv^2}{R} \cos \theta = mg \sin \theta + \mu N$$

$$\frac{mv^2}{R} \cos \theta = mg \sin \theta + \mu (mg \cos \theta + \frac{mv^2}{R} \sin \theta)$$

$$\frac{mv^2}{R} (\cos \theta - \mu \sin \theta) = mg (\sin \theta + \mu \cos \theta)$$

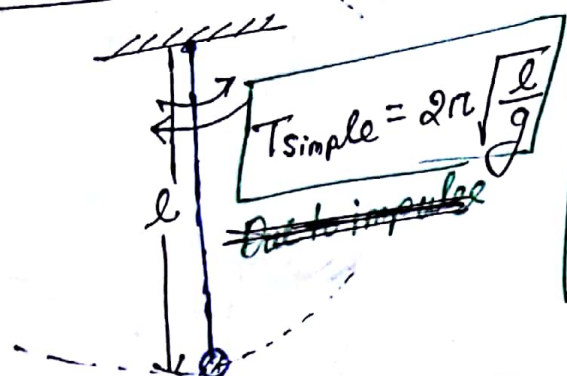
$$v_{max} = \sqrt{Rg \left(\frac{\sin \theta + \mu \cos \theta}{\cos \theta - \mu \sin \theta} \right)}$$

$$v_{min} = \sqrt{Rg \left(\frac{\sin \theta - \mu \cos \theta}{\cos \theta + \mu \sin \theta} \right)}$$

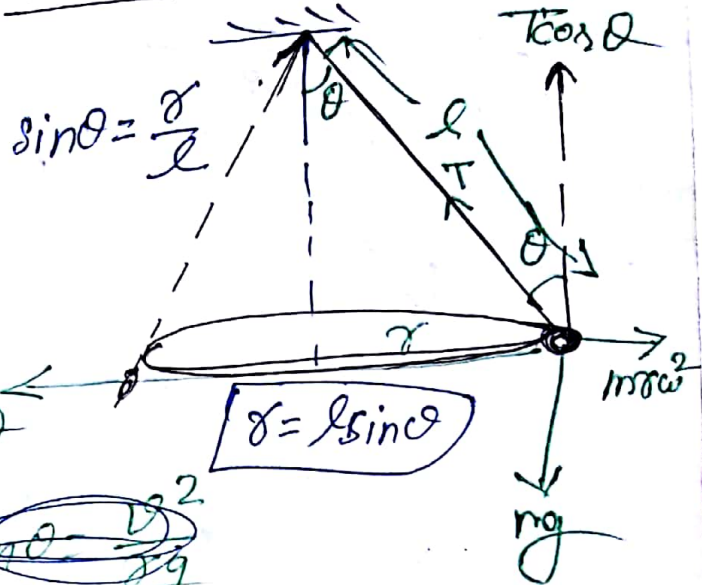
if $\mu=0$ $v_{safe} = \sqrt{Rg \tan \theta}$

$v_{safe} = \sqrt{Rg \frac{h}{b}}$

Conical Pendulum $\Rightarrow$



Due to impulse



$$\frac{T \sin \theta}{T \cos \theta} = \frac{m r \omega^2}{m g}$$

~~$\tan \theta = \frac{v^2}{r g}$~~

$$\frac{\sin \theta}{\cos \theta} = \frac{l \sin \theta \omega^2}{g}$$

~~$\omega = \frac{\sin \theta}{\cos \theta} = \frac{v^2}{r g}$~~

$$\omega = \sqrt{\frac{g}{l \cos \theta}}$$

$$T_{conical} = 2\pi \sqrt{\frac{l \cos \theta}{g}}$$

$$\frac{T_s}{T_c} = \sqrt{\cos \theta}$$

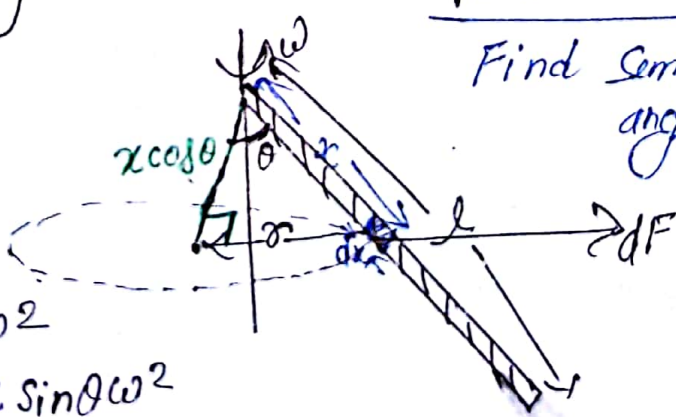
mass of rod = m

Find Semi Cone angle.

Q. $\lambda = m/l$

$dm = \lambda dx$

$$dF = dm r \omega^2 = \lambda dx \cdot x \sin \theta \omega^2$$



$d\tau = dF \times x \cos \theta$

$$\tau = \int \lambda \sin \theta \cos \theta \omega^2 x^2 dx$$

$$\tau = \frac{\lambda \sin 2\theta}{2} \omega^2 \frac{l^3}{3}$$

$$= \frac{m}{l} \sin 2\theta \frac{\omega^2 l^3}{3}$$

Pseudo Torque

$$\tau = \frac{m l^2}{3} \sin \theta 2\theta$$

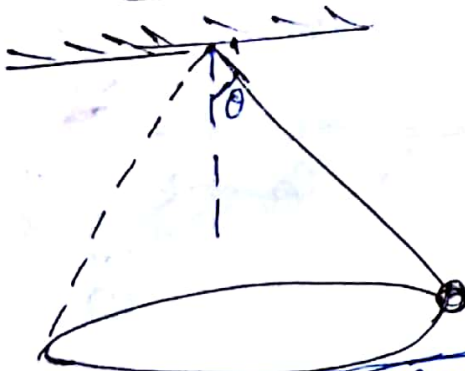
Real Torque $\tau = mg \frac{l}{2} \sin \theta$

~~$m \frac{1}{2} l \omega^2$~~ $2 \sin \theta \cos \theta = mg \frac{l}{2} \sin \theta$

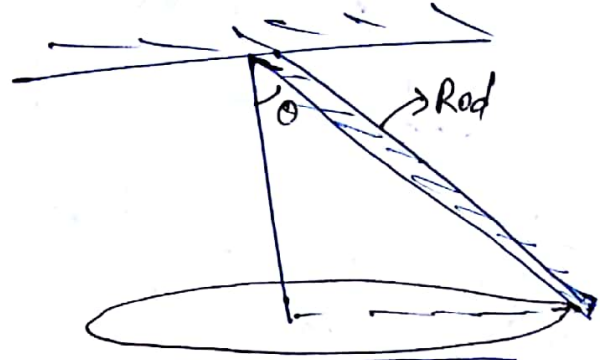
$\frac{l \omega^2}{3} \cos \theta = g/2$

$\omega = \sqrt{\frac{3g}{2l \cos \theta}}$

$T = 2\pi \sqrt{\frac{2l \cos \theta}{3g}}$



$T_{conical} = 2\pi \sqrt{\frac{l \cos \theta}{g}}$



$T_{conical} = 2\pi \sqrt{\frac{2l \cos \theta}{3g}}$

Death well rotor

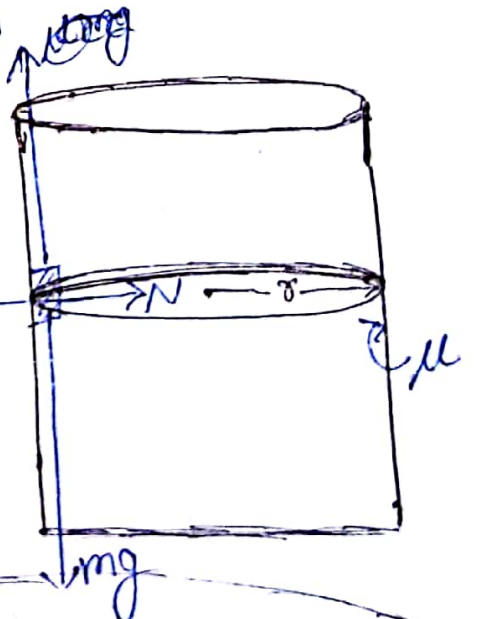
$N = mg$

$\mu \frac{mv^2}{r} = mg$

$v = \sqrt{\frac{rg}{\mu}}$

(Horizontal Circular track in vertical plane)

$v \propto \frac{1}{\sqrt{\mu}}$

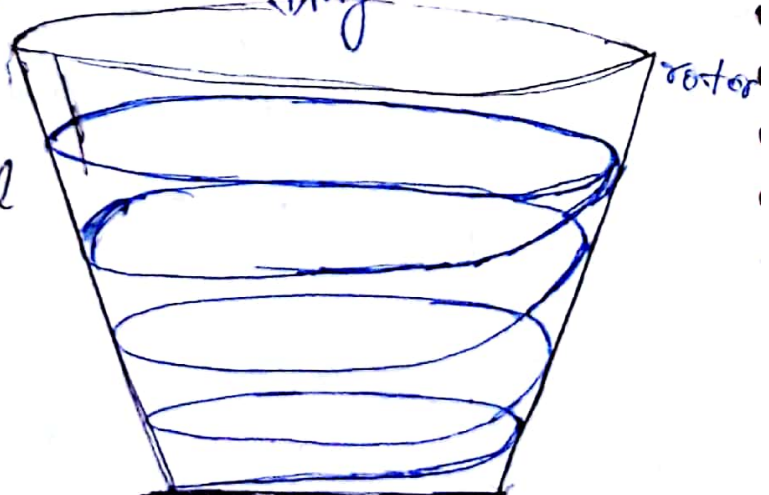


(Horizontal Circular track in Horizontal plane)

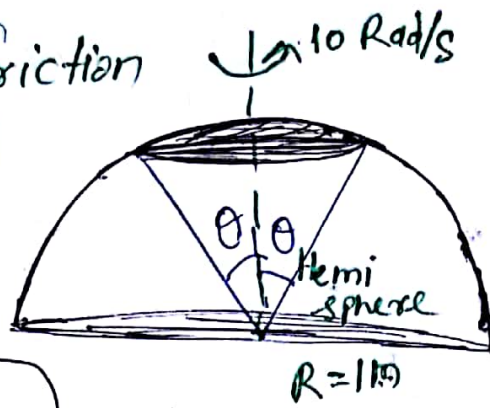
$v = \sqrt{\mu rg}$

$v \propto \sqrt{\mu}$

Helical path.



Q $\Rightarrow$ Find Coefficient of friction
b/w dust and wall for which
20% dust deposited on
surface during rotation.

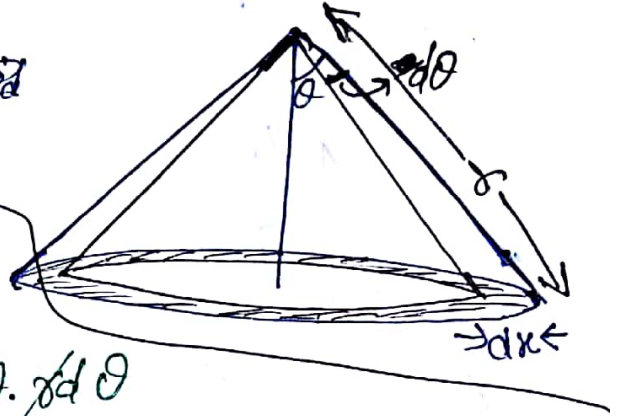


$\theta \rightarrow$ semi cone angle
Solid angle ($d\Omega$)
Solid angle

$$= \frac{A_{eq}}{r^2}$$

$$d\Omega = \frac{2\pi r \cdot dx}{r^2} \Rightarrow \frac{2\pi r \sin\theta \cdot r d\theta}{r^2}$$

$$\Omega = 2\pi \int_0^\theta \sin\theta d\theta$$



$$\Omega = 2\pi(1 - \cos\theta)$$

Now question $\Rightarrow$

Area of deposited dust = 20% of $2\pi R^2$
 $2\pi(1 - \cos\theta)R^2 = 0.2(2\pi R^2)$

$$1 - \cos\theta = 0.2$$

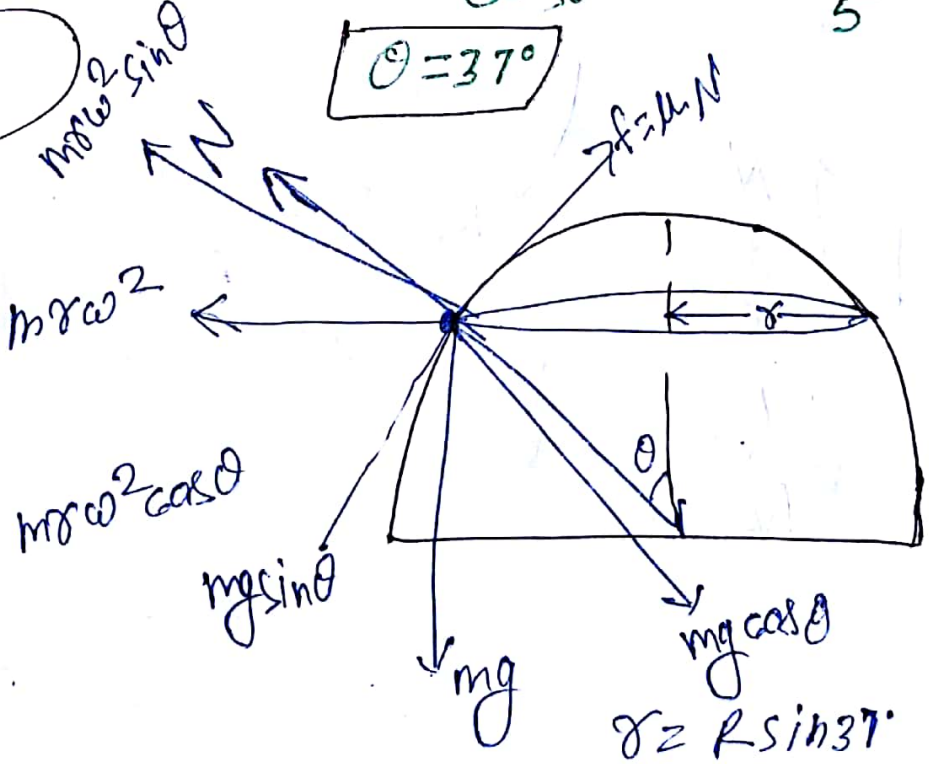
$$\cos\theta = 0.8 = \frac{4}{5}$$

$$\mu = \tan 37^\circ$$

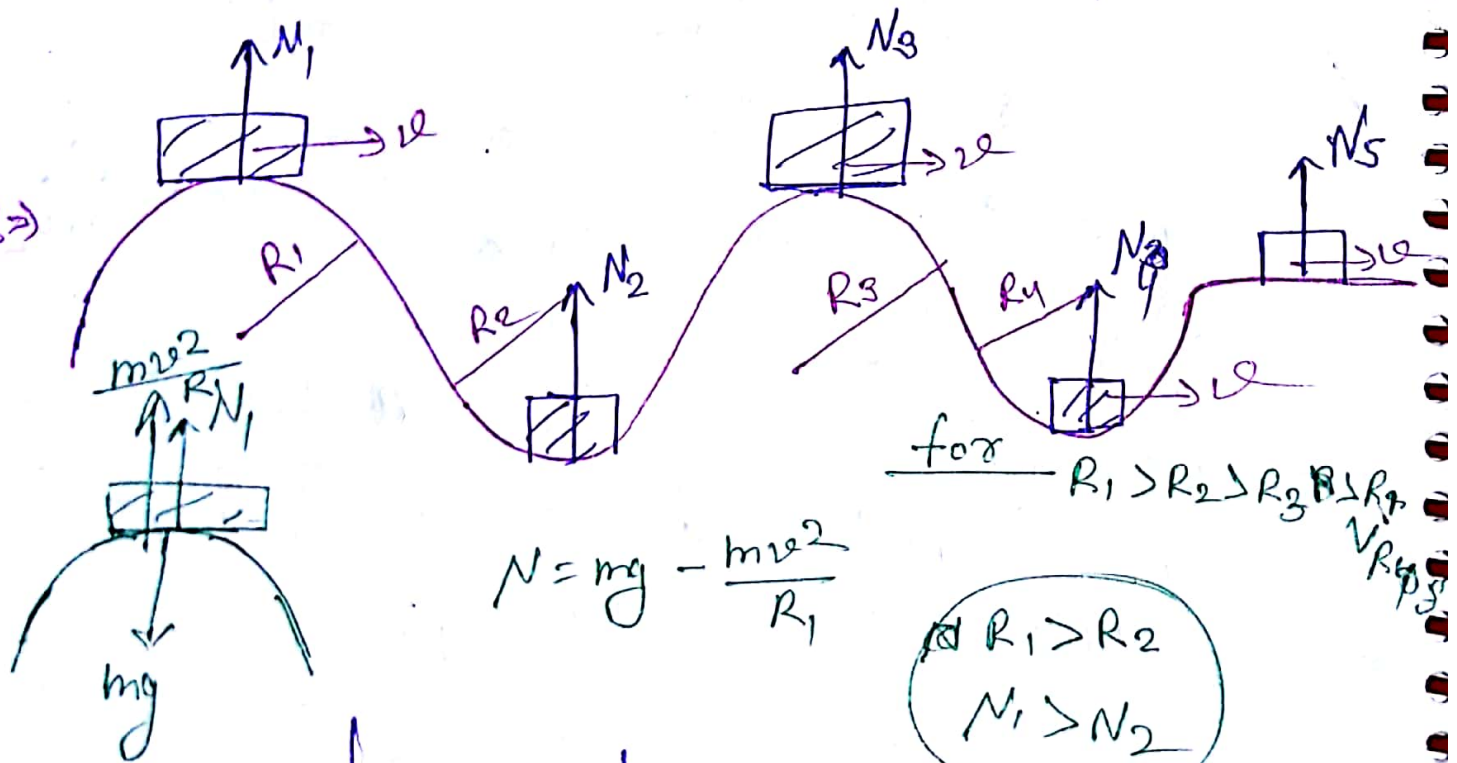
$$\theta = 37^\circ$$

for advanced $\Rightarrow$

$\mu = ?$



Q)



$$N = mg - \frac{mv^2}{R_1}$$

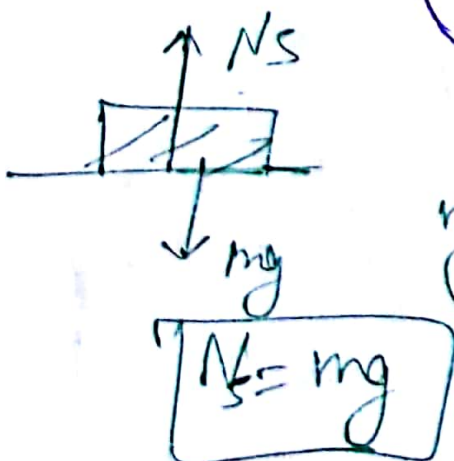
for $R_1 > R_2 > R_3 > R_4$
 $N_1 > N_2$

$$N_2 = mg + \frac{mv^2}{R_2}$$

$$R_4 > R_2$$

$$N_2 > N_4$$

$$N \propto \frac{1}{R}$$



$$N_5 = mg$$

Normal force in increasing order

$mg -$

mg

$mg +$

$$N_2 > N_3 > N_5 > N_4$$

$$(N_4 < N_3 < N_5 < N_4 < N_2)$$

Q=

also find
 $h = ?$

$$N = 0$$

$$mg \cos \theta = \frac{mv_1^2}{R}$$

$$g \cos \theta = \frac{u^2 + 2gr(1 - \cos \theta)}{R}$$

$$Rg \cos \theta = \frac{v^2 + 2gR - 2gR \cos \theta}{R}$$

$$3gR \cos \theta = v^2 + 2gR$$

$$\cos \theta = \frac{v^2 + 2gR}{3gR}$$

Here $v = \sqrt{2gh} = \sqrt{gR}$

$$\cos \theta = 1 \quad \theta = 0$$

find $x = ?$ (Projectile)

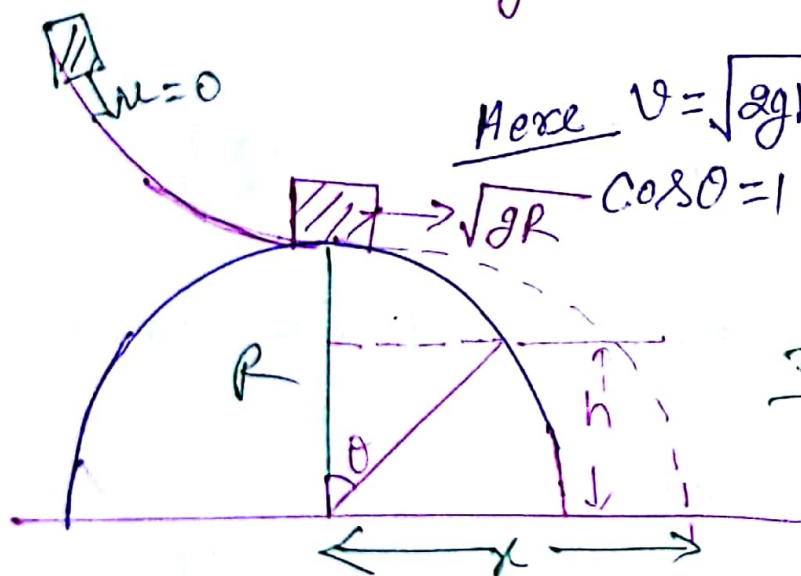
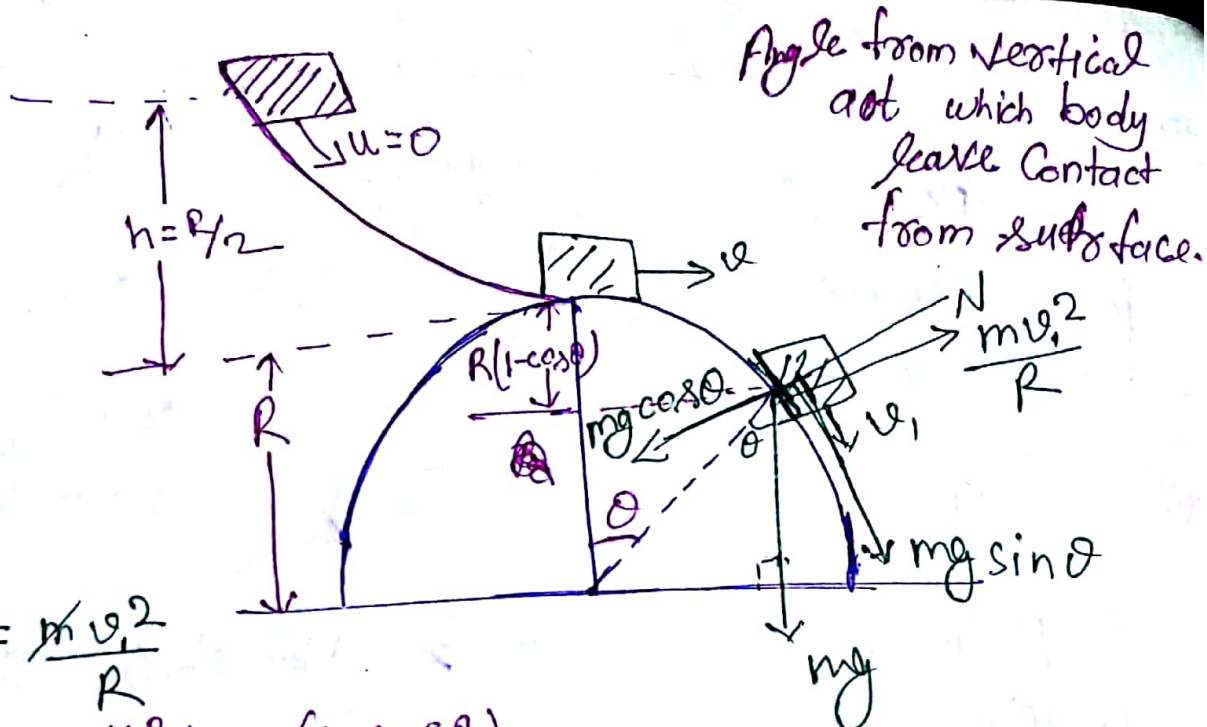
$$x = u \sqrt{\frac{2h}{g}}$$

$$x = \sqrt{gR} \cdot \sqrt{\frac{2 \cdot R}{g}} =$$

$$x = R\sqrt{2}$$

$$\cos \theta = \frac{2}{3} \quad \cos \theta = \frac{2}{3}$$

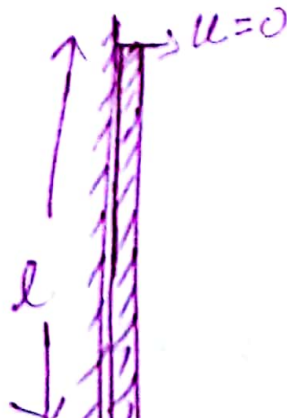
Angle from vertical
at which
compressive force
become ~~zero~~
Tensile.

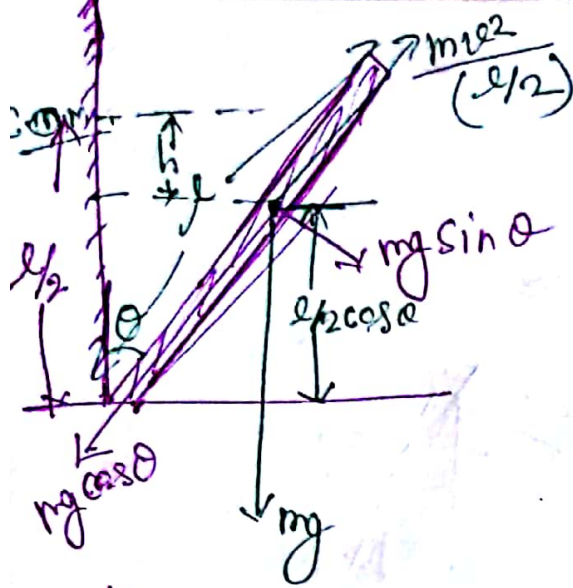


$$\cos \theta = \frac{u^2 + 2gh}{3gR} \quad u = 0$$

$$h = R \cos \theta = \frac{2R}{3}$$

Q=





Compressive force $\rightarrow$ Tensile

$$\frac{mv^2}{(l/2)} = mg \cos \theta \quad N=0$$

$$2gh = g \cos \theta \cdot \frac{l}{2}$$

$$2h = \frac{l}{2} \cos \theta$$

$$2 \cos \theta \cdot \frac{l}{2} (\cos \theta) = \frac{l}{4}$$

$$\cos \theta = \frac{2}{3}$$

Motion in vertical circle Non Uniform Circular motion

$$\omega = f(t)$$

$$\frac{d\omega}{dt} = \alpha \quad (\text{Angular acceleration})$$

$$\frac{d}{dt} \left(\frac{v}{r} \right) = \alpha \quad \frac{1}{r} \frac{dv}{dt} = \alpha \quad \frac{1}{r} a = \alpha$$

$$a = r\alpha$$

$$\textcircled{2} \quad \alpha = \text{Const}$$

$$\int_{\omega_0}^{\omega} d\omega = \alpha \int_0^t dt$$

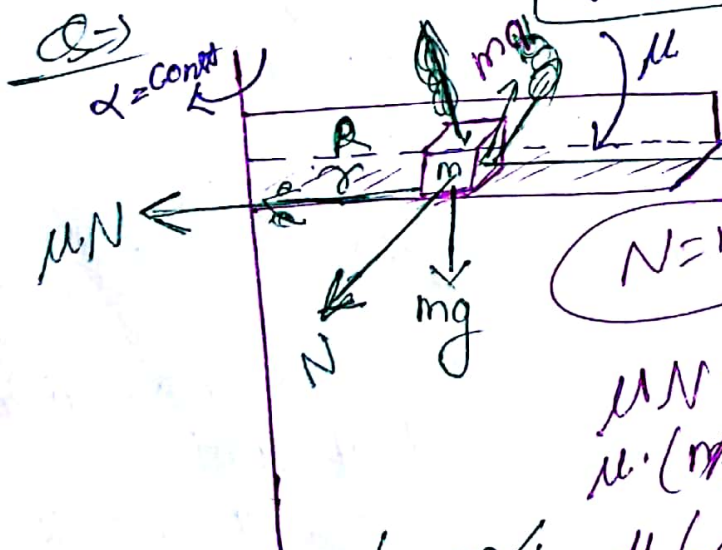
$$\omega = \omega_0 + \alpha t$$

$$\omega = \omega_0 + \alpha t$$

$$\theta = \omega_0 t + \frac{1}{2} \alpha t^2$$

$$\omega^2 = \omega_0^2 + 2\alpha\theta$$

$$\theta_t^{\text{th}} = \omega_0 t + \frac{1}{2} \alpha (2t-1)$$



Find Time after which block can slip.

$$N = mg$$

$$\mu N = m r \omega^2$$

$$\mu (mg) = m r \omega^2$$

$$\mu (a r) = r \omega^2$$

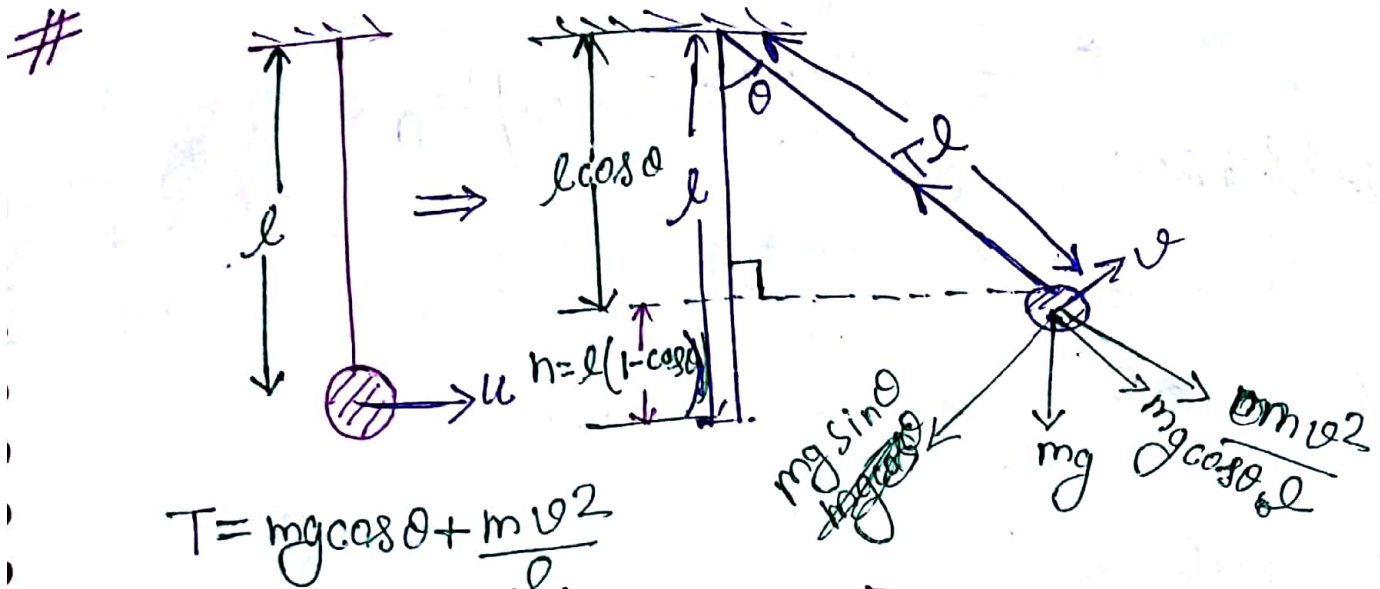
$$\mu \alpha = \omega^2$$

$$a = r\alpha$$

$$\mu \alpha = (\alpha t)^2$$

$$\mu = t^2 \alpha$$

$$t = \sqrt{\frac{\mu}{\alpha}}$$



$$T = mg \cos \theta + \frac{mv^2}{l}$$

$$T = mg \cos \theta + m[u^2 - 2gl(1 - \cos \theta)]$$

$$T = \frac{mu^2}{l} + mg(3 \cos \theta - 2)$$

For looping the loop $\Rightarrow T \neq 0 \quad v \neq 0$

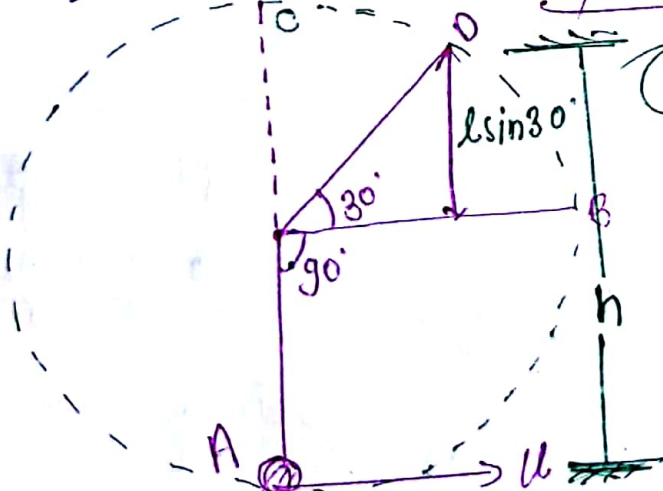
At $\theta = 180^\circ$ Tension is minimum.

$$T_{\min} > 0 \quad \frac{mv^2}{l} + mg(-3 - 2) > 0$$

$$\frac{mv^2}{l} > 5mg > 0$$

$\theta = 180^\circ$

$$u > \sqrt{5gl}$$



(1) At A $\theta = 0^\circ$

$$u_A > \sqrt{5gl}$$

$$T = \frac{mu^2}{l} + mg(3 \cos \theta - 2)$$

$$T > 5mg + mg(3 \cos \theta - 2)$$

$$T_A > 6mg$$

(2) At B $\theta = 90^\circ$

$$v_B^2 = v_A^2 - 2gl$$

$$\Rightarrow 5gl - 2gl$$

$$v_B > \sqrt{3gl}$$

$$T_B = \frac{mv_B^2}{l} + mg(3 \cos \theta - 2)$$

$$T_B > 3mg$$

III $\theta = 120^\circ$
At D

$$T_D = \frac{mu^2}{l} + mg(3\cos 120^\circ - 2)$$

$$T_D > \left[5mg + \left(-\frac{7}{2}\right)mg \right] \quad T_D > \frac{3mg}{2}$$

$$h = l + l \sin 30^\circ = \frac{3l}{2}$$

$$v_0^2 = v_A^2 - 2g \frac{3l}{2}$$

$$v_0 > \sqrt{2gl}$$

IV at C

$$v_C^2 = v_A^2 - 2g \cdot 2l$$

$$v_C > \sqrt{gl}$$

$$T_C = \frac{mv_C^2}{l} - 5mg$$

T_C

Oscillation	Leaving its path	Looping the loop
$T \neq 0$ $v = 0$	$T = 0$ $v \neq 0$	$T \neq 0$ $v \neq 0$
$h_1 = \frac{u^2}{2g}$	$\sqrt{2gl} < u < \sqrt{5gl}$	$u > \sqrt{5gl}$
	$h_2 = \frac{u^2 + gl}{3g}$	$T \neq 0$ $v \neq 0$

For oscillating $v = 0$ $T \neq 0$

$$0 = u^2 - g - 2gh_1$$

$$h_1 = \frac{u^2}{2g}$$

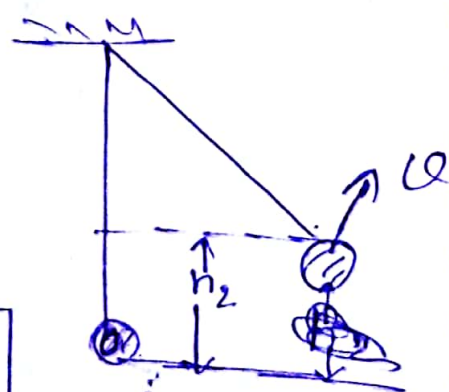
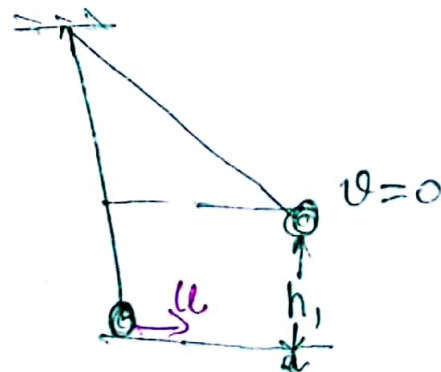
height at which body start oscillating.

For leaving its path $T = 0$ $v \neq 0$

$$\frac{mu^2}{l} + mg(3\cos \theta - 2) = 0$$

$$\frac{mu^2}{l} + mg \left(3 \cdot \left(\frac{l - h_2}{l} \right) - 2 \right) = 0$$

$$h_2 = \frac{u^2 + gl}{3g}$$



For Oscillation $T \neq 0$ & $v = 0$

Velocity vanishes before Tension $\frac{u^2}{2g} < \frac{h_1 < h_2}{u^2 + gl}$

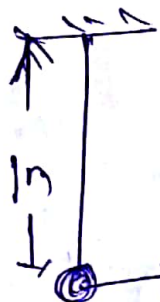
For leaving its path $\Rightarrow 3u^2 < 2u^2 + 2gl$

Tension vanishes before velocity

$$u > \sqrt{2gl}$$

$$v < \sqrt{2gl}$$

Q $\Rightarrow$



Type of motion
 $u < \sqrt{2gl}$
(Oscillatory motion)

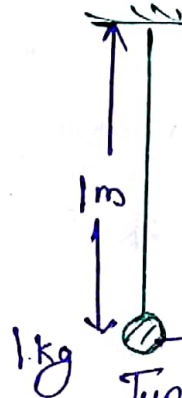
$$\theta = 180^\circ$$

$$T = \frac{mu^2}{l} + mg(3\cos\theta - 2)$$

$$T = 70 + 10(-3 - 2)$$

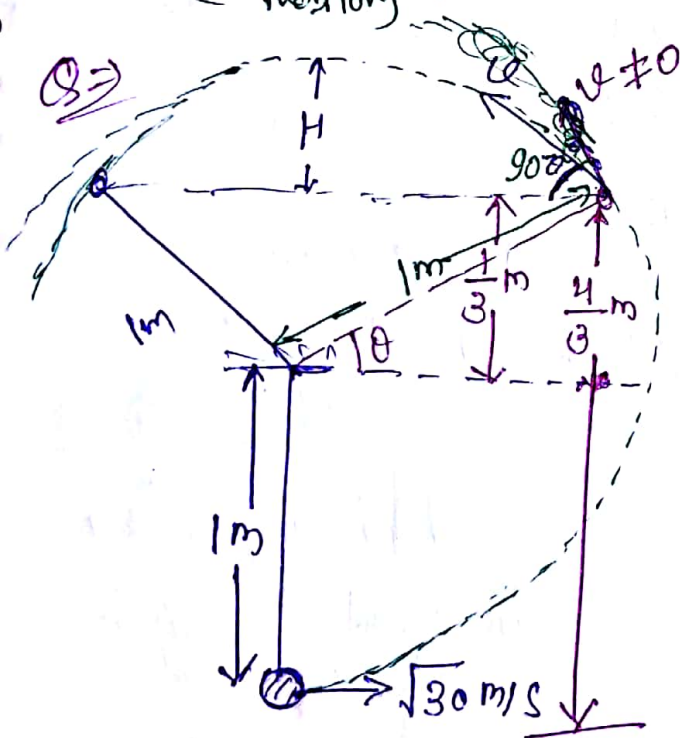
$$T \Rightarrow 20 \text{ N}$$

$$u > \sqrt{5gl}$$



Type of motion $\rightarrow$ looping the loop
Tension at max height $\rightarrow$ loop

Q $\Rightarrow$



$$\sin\theta = \frac{1}{3} \quad \cos\theta = \frac{\sqrt{8}}{3}$$

$$\text{speed } v = \sqrt{30 - 2g \times \frac{4}{3}} = \sqrt{\frac{10}{3}}$$

max height up to which ball can move.

$$u < \sqrt{5gl}$$

$$u > \sqrt{2gl} \quad (\text{leaving its path})$$

$$h = \frac{u^2 + gl}{2g} = \frac{30 + 10}{30} \Rightarrow \frac{4}{3} \text{ m}$$

$$H = \frac{u^2 \sin^2(90 - \theta)}{2g}$$

$$\frac{v^2 \cos^2\theta}{2g} \Rightarrow \frac{10}{3} \times \frac{8}{10 \times 9.8} \Rightarrow \frac{4}{27} \text{ m}$$

max height $\Rightarrow$

$$\frac{4}{3} + \frac{4}{27} = \frac{40}{27} \text{ m}$$

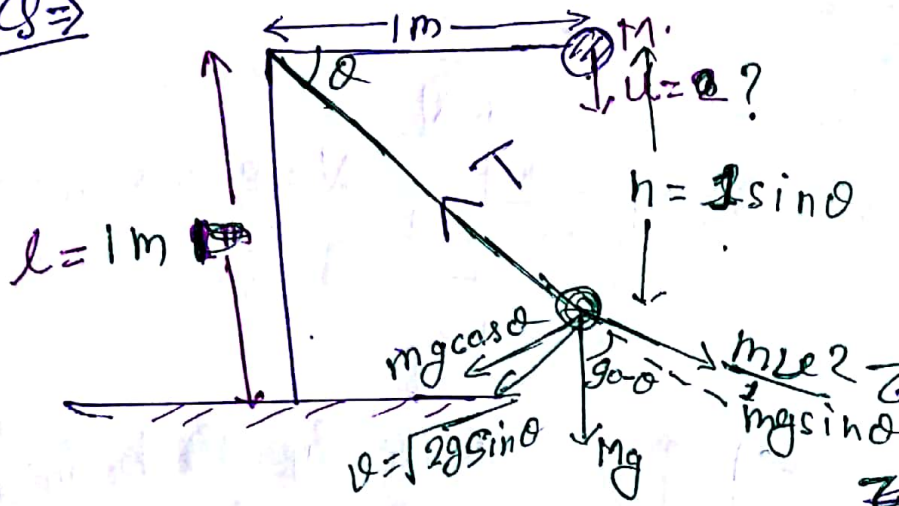
$$\tan \theta = \frac{g \cos \theta}{2g \sin \theta}$$

$$\Rightarrow \tan^2 \theta = \frac{1}{2}$$

$$\tan \theta = \frac{1}{\sqrt{2}}$$

$$\theta = \tan^{-1} \frac{1}{\sqrt{2}}$$

Q $\Rightarrow$



find max Torque on stand.

also find angle $\theta = ?$

$l = 1$

$$T = mg \sin \theta + \frac{mv^2}{l}$$

$$\Rightarrow mg \sin \theta + m \cdot 2g \sin \theta$$

$$T = 3mg \sin \theta$$

$$\tau = T \times l \cos \theta$$

$$\Rightarrow 3mg l \cos \theta \sin \theta$$

$$\Rightarrow 3mg l \sin 2\theta$$

$$\tau = \frac{3mg l \sin 2\theta}{2}$$

$\tau \rightarrow \max$

$$\sin 2\theta = 1$$

$$\theta = 45^\circ$$

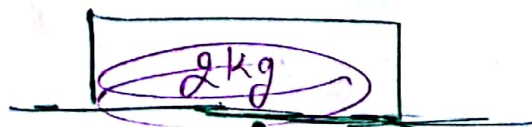
$$\tau = \frac{3}{2} mgl$$

$$\tau \propto l$$

for $l = 1m$

$$\tau = \frac{3}{2} mg$$

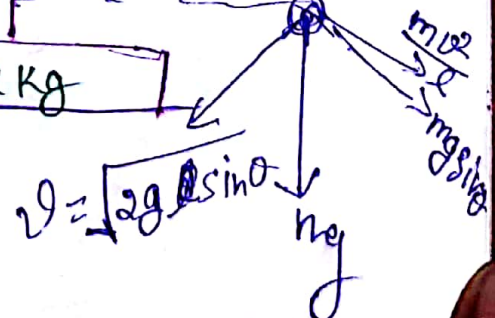
Q $\Rightarrow$



find angle θ from horizontal at which body can slip.

$\mu = 0.1$

2kg



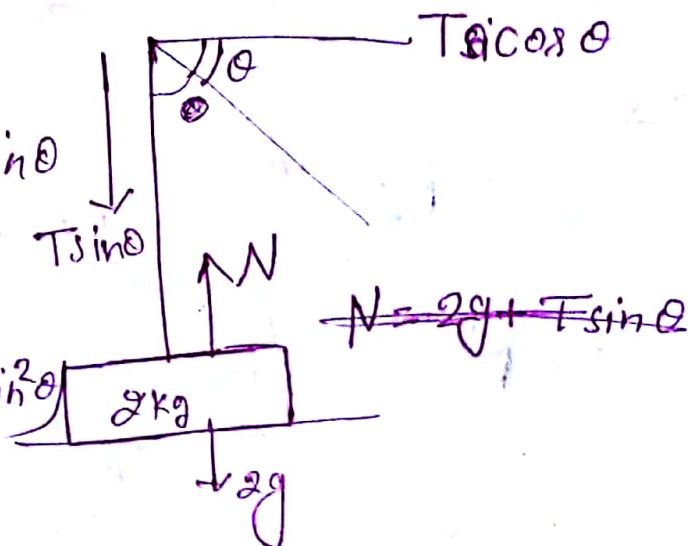
$$T = 3g \sin \theta$$

$$T \cos \theta = \mu N \quad N = 2g + T \sin \theta$$

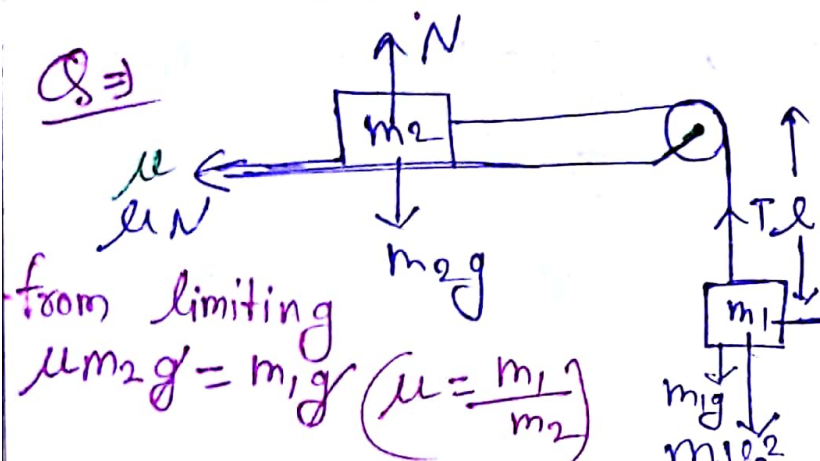
$$T \cos \theta = 0.1(2g + T \sin \theta)$$

$$3g \sin \theta \cos \theta = 0.1(2g + 3g \sin^2 \theta)$$

$$\theta = ?$$



Q3



from limiting
 $\mu m_2 g = m_1 g \quad (\mu = \frac{m_1}{m_2})$

Initially the body is in a limiting equilibrium.

find Radius of Circular track in which block A can move just after sharp blow.

$$T = m_1 g + \frac{m_1 v_0^2}{l}$$

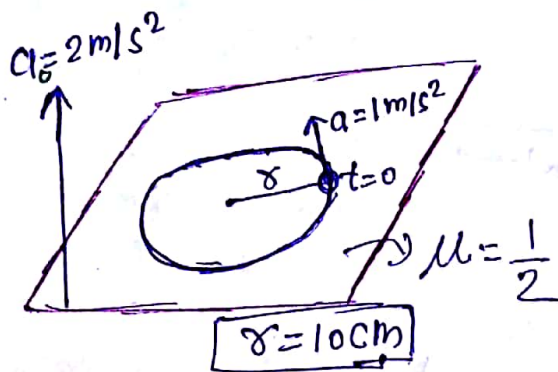
$$T = \mu m_2 g \quad \mu m_2 g = m_1 g + \frac{m_1 v_0^2}{l}$$

$$a = \frac{m_1 g + \frac{m_1 v_0^2}{l}}{m_1 + m_2} - \mu m_2 g$$

$$a = \frac{m_1 v_0^2}{l(m_1 + \frac{m_1}{\mu})} \quad a = \frac{m_1 v_0^2}{l(m_1 + m_2)} = \frac{v_0^2}{r}$$

$$r = l(1 + \frac{1}{\mu})$$

Q₃ ⇒



Find max distance covered by orbiting body in track before slip.

$$v^2 = 2as$$

$$v^2 = 2 \times 1 \times s$$

$$s = \frac{v^2}{2}$$

$$f = ma_{net}$$

$$\mu mg (g + a_0) = m \sqrt{a_r^2 + a_n^2}$$

$$\frac{1}{2} (10 + 2) = \sqrt{1^2 + \left(\frac{v^2}{r}\right)^2}$$

$$36 = 1 + \left(\frac{2s}{0.1}\right)^2$$

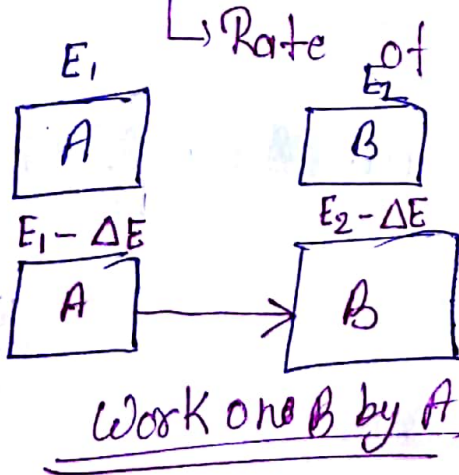
$$s = \frac{1}{20} \sqrt{35}$$

~~35 x 0.01 = 0.35~~

Work / Energy / Power ⇒

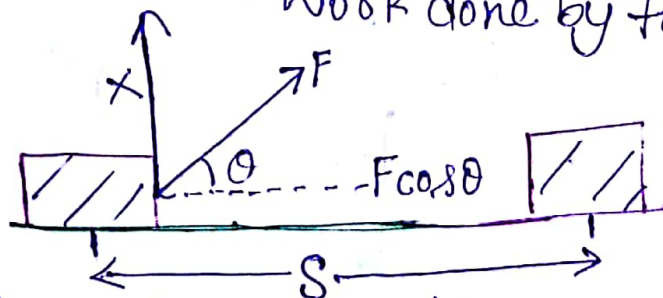
Work ⇒ A process by which Energy transfer from one body to other.

Power ⇒ Rate change in transfer of Energy.



Work ⇒ Body should be displaced in the direction of force.

• Work done by force



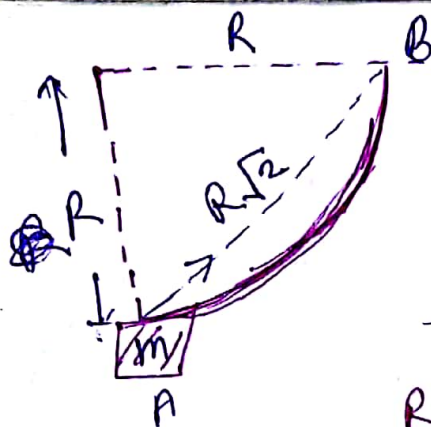
$$W = (F \cos \theta) s$$

$$W = \vec{F} \cdot \vec{s}$$

$$W = \vec{F} \cdot \vec{s} \quad \vec{F} = \text{const.}$$

$$W = \int \vec{F} \cdot d\vec{s} \quad \vec{F} \rightarrow \text{Variable}$$

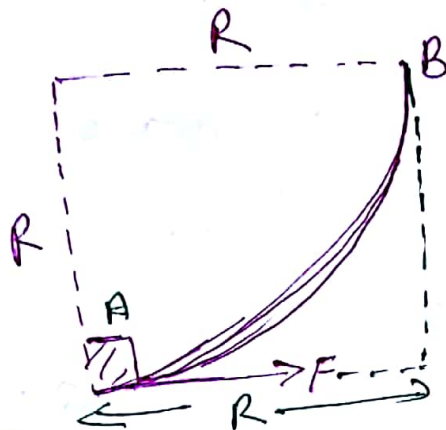
Q3)



WA→B along the path
Under given force F.

$$W = F R \sqrt{2}$$

Q3)

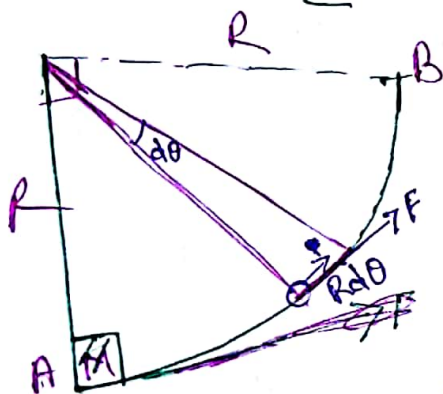


$$W_{A \rightarrow B} = F \cdot R$$

$$\vec{F} = F \hat{i} \quad \vec{r} = R \hat{i} + R \hat{j}$$

$$W = \vec{F} \cdot \vec{r} = FR$$

Q4



WA→B along the path under
Tangential force F = ?

$$dW = \vec{F} \cdot d\vec{s}$$

$$= FR d\theta \cos 0^\circ$$

$$W = FR d\theta$$

$$W = FR \int_0^{\pi/2} d\theta$$

$$W = \frac{FR\pi}{2}$$

Work done by force

$$W_{\text{net}} = \int F_{\text{net}} ds \Rightarrow \int m a \cdot ds \Rightarrow \int m \cdot \frac{dv}{dt} \cdot \frac{ds}{dt} dt$$

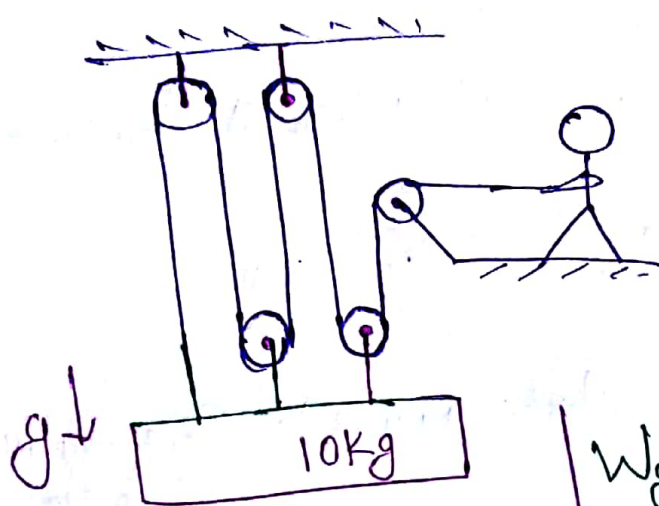
$$W_{\text{net}} = m \int_{v_i}^{v_f} v dv \Rightarrow \frac{1}{2} m (v_f^2 - v_i^2)$$

$$W_{\text{net}} = K_f - K_i$$

$$W_{\text{net}} = \Delta K$$

$$W_{\text{Conservative}} + W_{\text{non-conservative}} + W_{\text{other}} = \Delta K$$

Q3



Work by man to lift up block by 2m.

From rest to rest

$$W_{\text{net}} = \Delta K$$

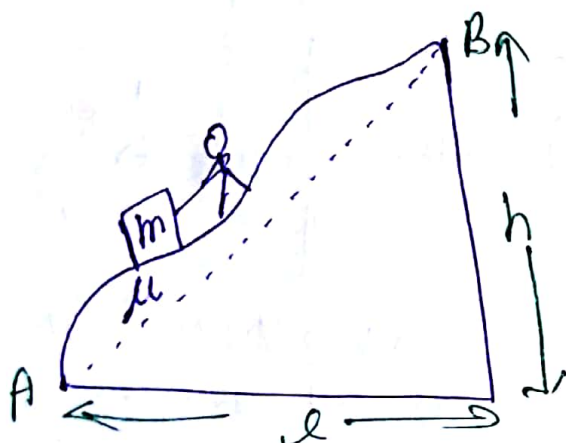
$$W_{\text{gravity}} + W_{\text{man}} = 0$$

$$W_{\text{man}} = mgh$$

$$W_{\text{man}} \Rightarrow 10 \times 10 \times 2 = 200 \text{ J}$$

Work done by man in displacing block from A to B along the path.

Q4



$$W_{\text{net}} = \Delta K$$

$$W_N + W_g + W_{fr} + W_{\text{man}} = 0$$

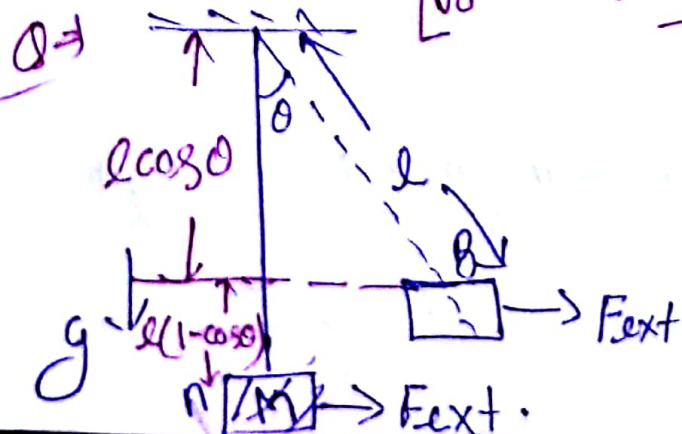
$$0 + (-mgs \sin \theta) + (-\mu mg \cos \theta ds) + dW_{\text{man}} = 0$$

$$mg(ds \sin \theta + \mu ds \cos \theta) = (dW)_{\text{man}}$$

$$mg(dy + \mu dx) = (dW)_{\text{man}}$$

$$W_{\text{man}} = mg \left[\int_0^h dy + \int_0^l dx \right]$$

$$W_{\text{man}} = mg(h + \mu l)$$



Work done by external force in displacing block from A to B

$$W_{gr} + W_{ext} = 0$$

$$-mgh(1 - \cos 80^\circ) + W_{ext} = 0$$

$W_{cons} + W_{non-cons} = \Delta K$

$W_{net} = \Delta K$

Potential energy $\Rightarrow$ Work against Conservative field or Conservative force.

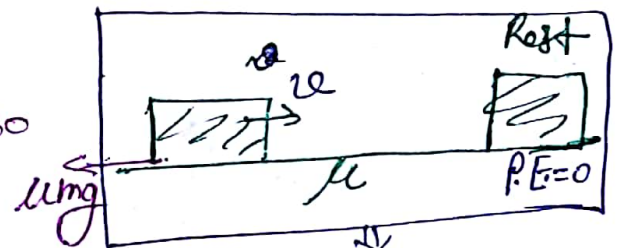


$$W = -\Delta U$$

$$= -\vec{F} \cdot \vec{s}$$

$$\Rightarrow -mgh \cos 180^\circ$$

$W = +mgh$



No potential energy in work against non-conservative force.

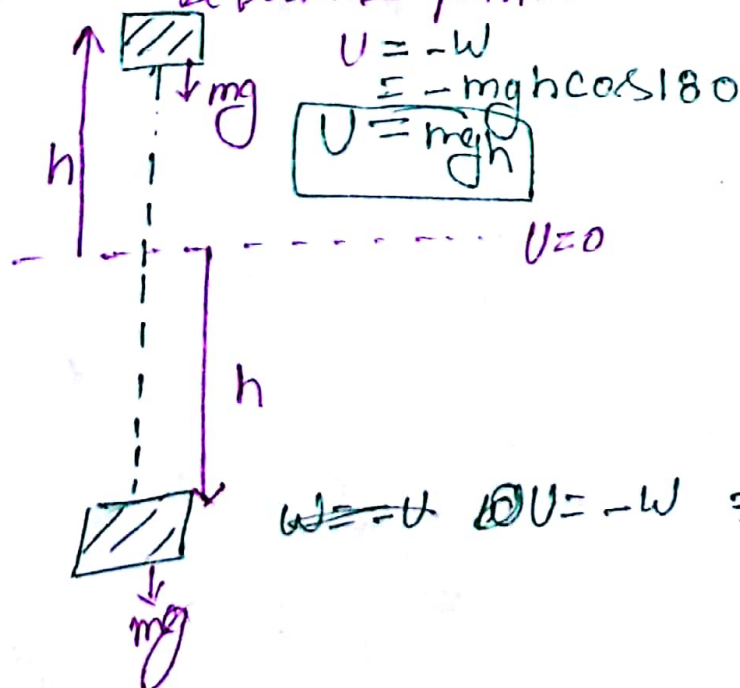
$dU = -dw$

$$dw = -dU$$

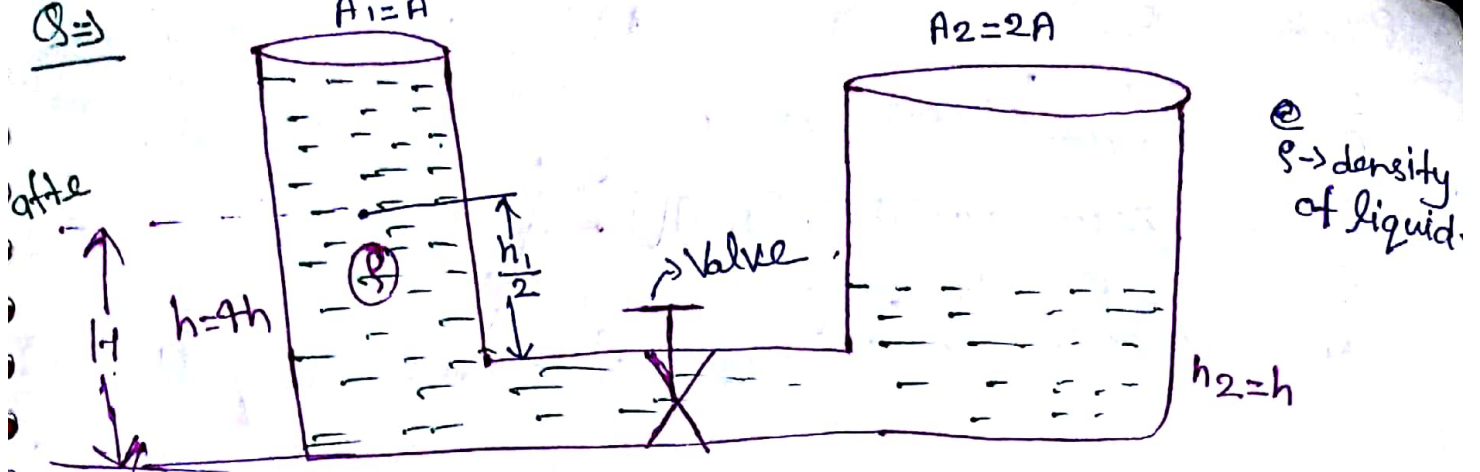
$$\int dw = - \int_{U_i}^{U_f} dU$$

$W_{conservative} = U_i - U_f = -\Delta U$

P.E. is Potential parameter always measured from reference point.



$$W = -\Delta U \quad \Delta U = -W \Rightarrow -mgh \cos 80^\circ \Rightarrow -mgh$$



$$W = U_i - U_f$$

$$U_i \Rightarrow m_1 g h_1 + m_2 g h_2$$

$$\Rightarrow (A_1 h_1 \rho) g \frac{h_1}{2} + (A_2 h_2 \rho) g \frac{h_2}{2}$$

$$U_i \Rightarrow \rho g \left[\frac{A_1 h_1^2 + A_2 h_2^2}{2} \right]$$

$$U_f = (A_1 H \rho g) \frac{H}{2} + (A_2 H \rho g) \frac{H}{2}$$

$$U_f \Rightarrow \rho g H^2 \left(\frac{A_1 + A_2}{2} \right)$$

after valve opened.

$h = ?$

Volume Const.

$$A_1 h_1 + A_2 h_2 = (A_1 + A_2) H$$

$$H = \frac{A_1 h_1 + A_2 h_2}{A_1 + A_2}$$

#

$$dU = -dw$$

$$dU = -F \cdot dx$$

$$F = -\frac{dU}{dx}$$

Conservative force.

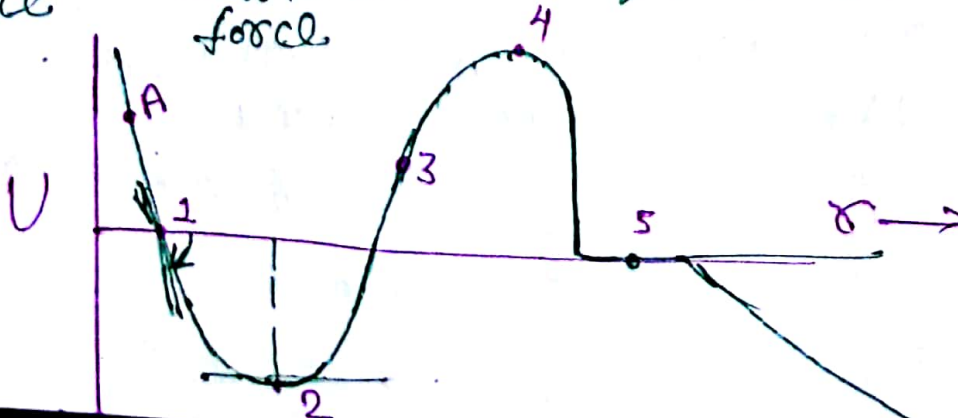
Conservative field

$$E = \frac{F}{M}$$

+ve
Repulsive force

-ve
Attractive force

Zero
Equilibrium



Point	Force
1 A	+ve +ve Repulsive
2	Zero

Point	Force
1	+ve
A	+ve
2	Zero (Equilibrium) [stable]
3	-ve (Attractive)
4	Zero (Equilibrium) [Unstable]
5	Zero (Equilibrium) [neutral]

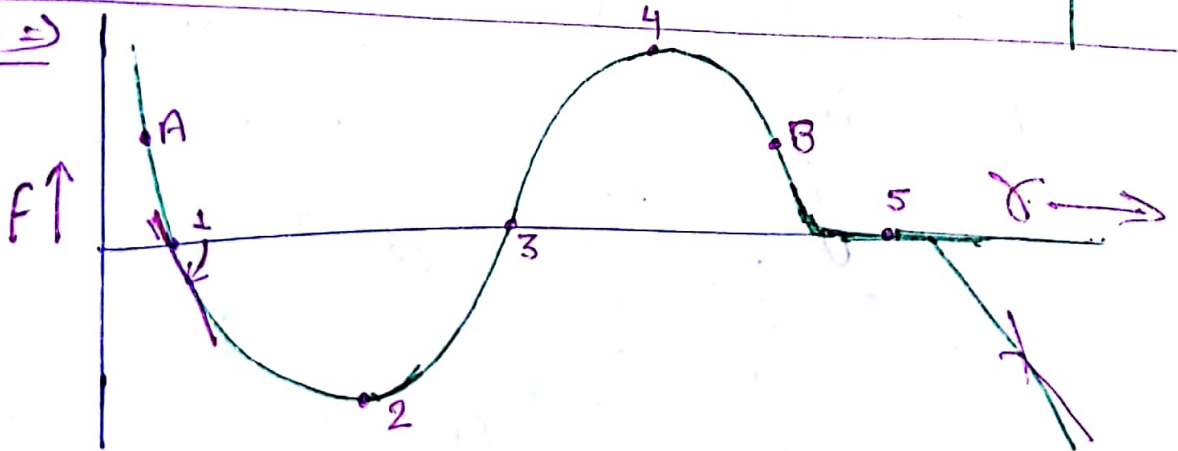
$\gamma_0 \rightarrow$ Inter molecular range
($\gamma_0 \approx 10^{-9}m$)
(In Equilibrium)

$U = \frac{a}{\gamma^6} - \frac{b}{\gamma^{12}}$
 $f=0$

Type of Equilibrium $\Rightarrow$

Type of Equilibrium	Force $F = -\frac{dV}{d\gamma}$	P. E. (U)	$\frac{d^2U}{d\gamma^2} \text{ or } -\frac{dF}{d\gamma}$	$\frac{dF}{d\gamma}$
• Stable	0	-ve	+ve	-ve
• Unstable	0	+ve	-ve	+ve
• neutral	0	0	0	0

Graph $\Rightarrow$



Point	F	$\frac{dF}{d\gamma}$
2	-ve (Attractive)	0 (Non-equilibrium)
A	+ve (Repulsive)	non-equilibrium
4	+ve	non-equilibrium
B	+ve	non-equilibrium
1	$F=0$	stable
3	$F=0$	Unstable
5	$F=0$	Neutral

$$\# W_{\text{cons}} + W_{\text{non-cons}} = \Delta K$$

$$-\Delta U + W_{\text{non-cons}} = \Delta K \Rightarrow$$

$$W_{\text{non-cons}} = \Delta K + \Delta U = (K_f - K_i) + (U_f - U_i)$$

$$= (K_f + U_f) - (K_i + U_i)$$

$$= E_f - E_i$$

$$W_{\text{non-cons}} = \Delta E$$

$$\begin{aligned} \bullet W_{\text{net}} &= \Delta K = K_f - K_i \\ \bullet W_{\text{cons}} &= -\Delta U = U_i - U_f \\ \bullet W_{\text{non-cons}} &= \Delta E = E_f - E_i \end{aligned}$$

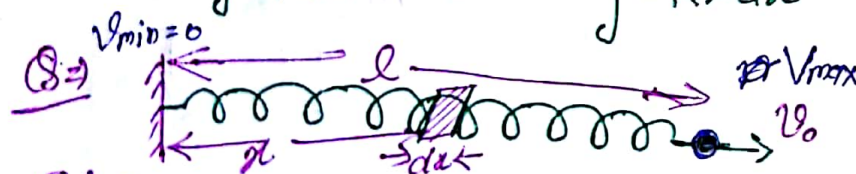
$E \rightarrow$ Mechanical energy.

Energy stored in spring $\Rightarrow$

$= -\text{Work by Conservative}$

$$= -\int F_{\text{sp}} dx \Rightarrow -\int -kx dx$$

$$U = \frac{1}{2} kx^2$$



Solve

$$\lambda = \frac{m}{l} \quad dm = \lambda dx$$

(1) Velocity of segment $= \left(\frac{v_0}{l}\right)x$ $m \rightarrow$ mass of spring
 $l \rightarrow$ natural length
 $x \rightarrow$ expansion in spring.
 $k \rightarrow$ force constant

$$dK = \frac{1}{2} dm v^2$$

$$\Rightarrow \frac{1}{2} \lambda dx \left(\frac{v_0}{l}\right)^2 x^2$$

$$\int dK = \frac{1}{2} \frac{M}{l} \frac{v_0^2}{l^2} \int_0^l x^2 dx$$

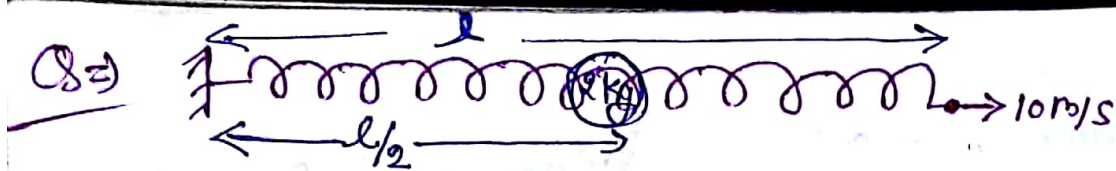
$$K = \frac{1}{2} \frac{m v_0^2}{l^3} \cdot \frac{l^3}{3}$$

$$K = \frac{1}{2} \frac{m}{3} (v_0^2)$$

$$m_{\text{eff}} = \frac{m}{3}$$

Massless spring $\frac{1}{2} kx^2 = \frac{1}{2} \frac{m}{3} v_0^2$

$$x = v_0 \sqrt{\frac{m}{K}}$$

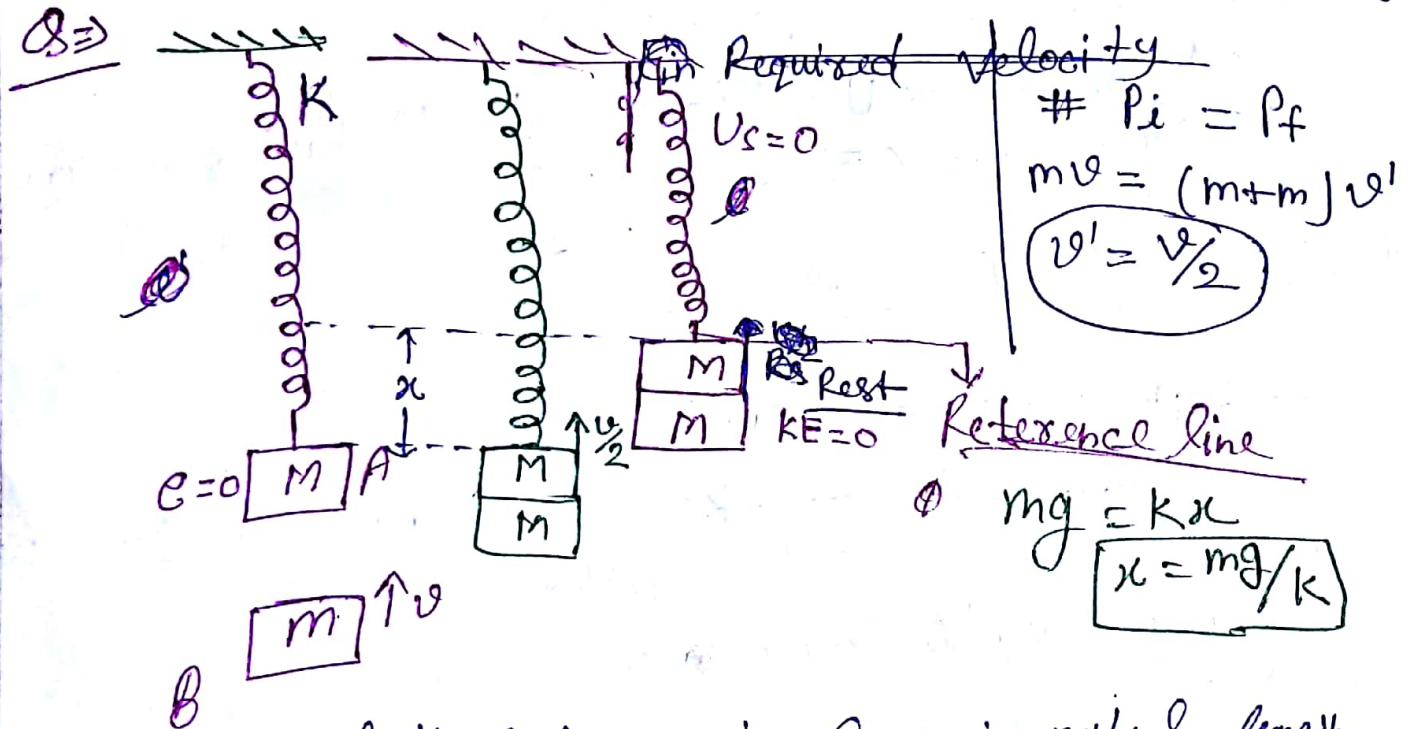


If mass of spring is 6 kg then find kinetic energy in system

$$K = \frac{1}{2} \times 10 \times 2 \times 5^2 + \frac{1}{2} \left(\frac{6}{3} \right) 10^2$$

$$K \Rightarrow 125 \text{ J}$$

In above problem then find expansion in spring.



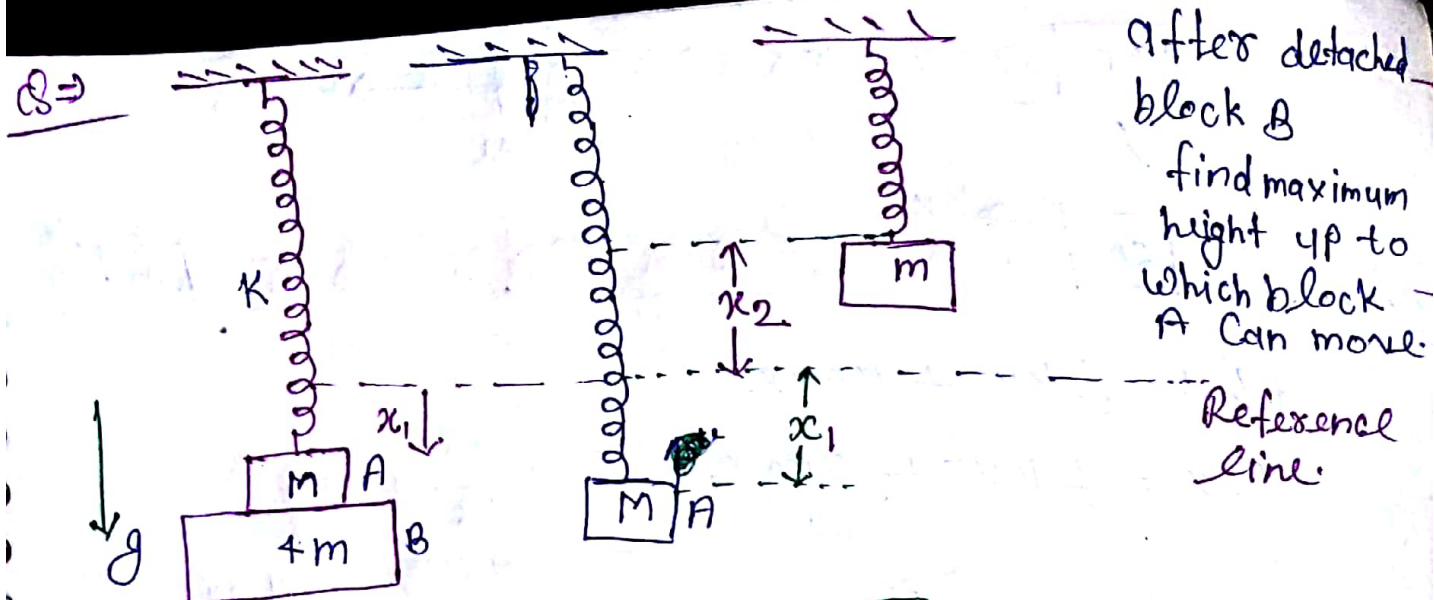
Required velocity v for spring comes in natural length.

$$E_i = E_f = 0$$

$$\frac{1}{2} m v^2 + \frac{1}{2} k x^2 + (-2mgx) = 0$$

$$\frac{m v^2}{4} + \frac{1}{2} k x^2 - 2mgx = 0$$

$$\frac{m v^2}{4} + \frac{1}{2} k \frac{m^2 g^2}{k^2} = 2mg - \frac{mg}{k}$$



Q = 5mg = kx₁
 $x_1 = 5mg/K$ — (1)

$E_i = E_f$
 $-mgx_1 + \frac{1}{2}Kx_1^2 = mgx_2 + \frac{1}{2}Kx_2^2$

$\frac{1}{2}K(x_1 - x_2)(x_1 + x_2) = mg(x_1 + x_2)$

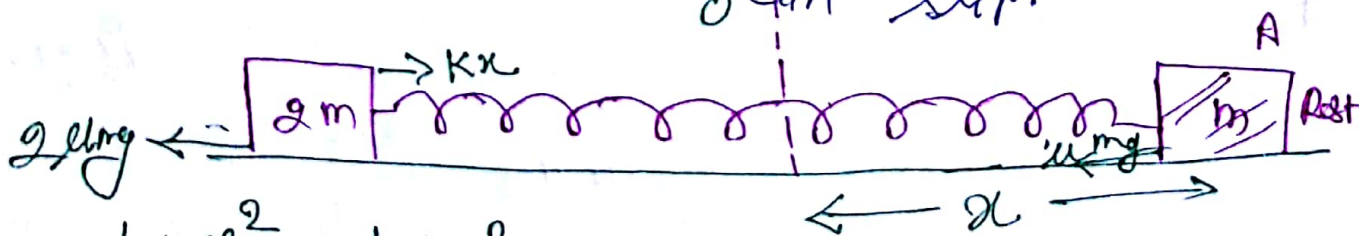
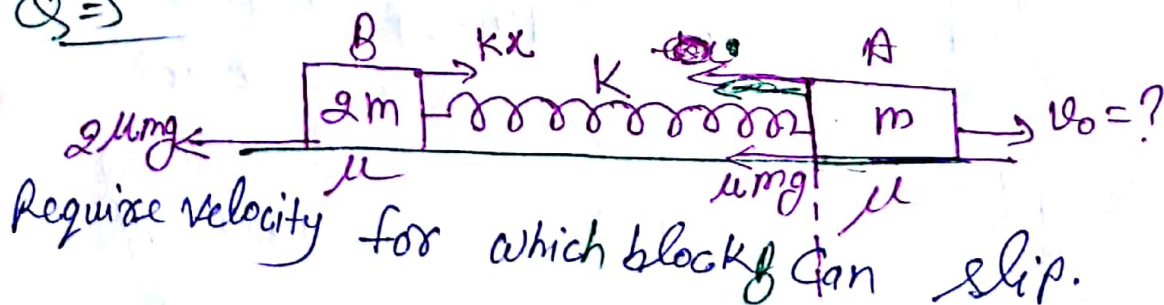
$x_1 - x_2 = \frac{2mg}{K}$

$x_2 = \frac{3mg}{K}$

$\frac{5mg}{K} - x_2 = \frac{2mg}{K}$

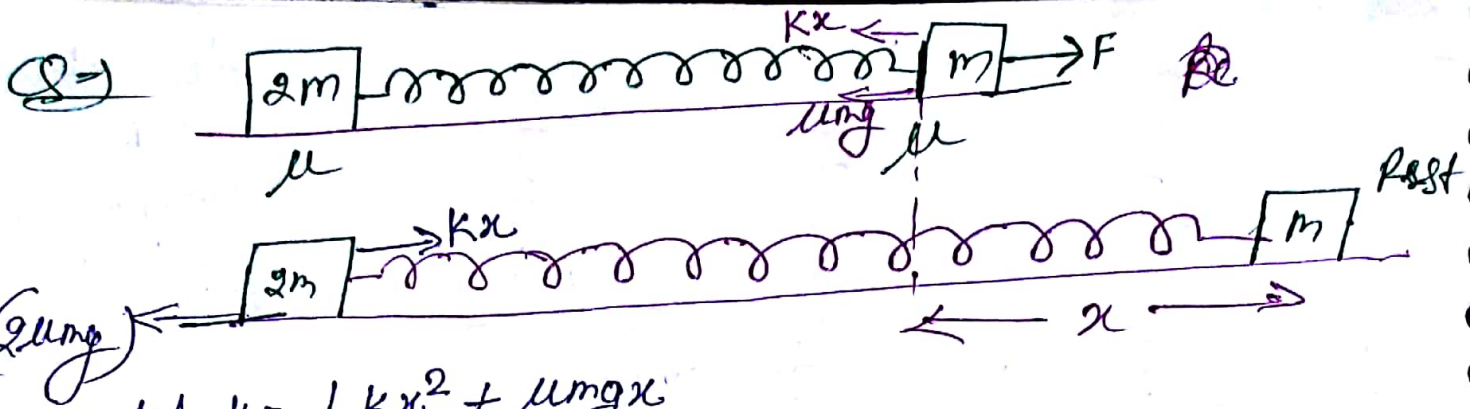
$h = x_1 + x_2$
 $h \Rightarrow \frac{5mg}{K} + \frac{3mg}{K} = \frac{8mg}{K}$

Q ⇒



$\frac{1}{2}mv_0^2 = \frac{1}{2}Kx^2 + \mu mgx$

$\frac{1}{2}mv_0^2 = \frac{1}{2}K\left(\frac{2\mu mg}{K}\right)^2 + \frac{2\mu^2 m^2 g^2}{K}$

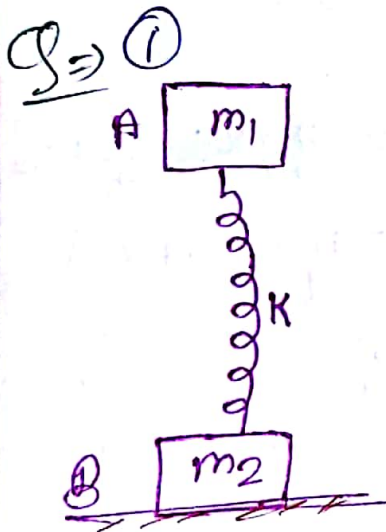


Work $k = \frac{1}{2} kx^2 + \mu mgx$

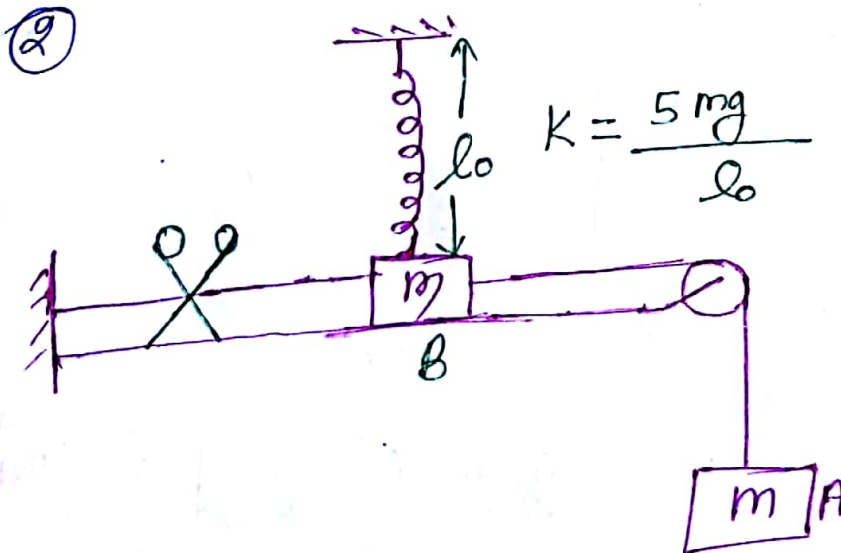
$F \cdot x = \frac{1}{2} kx^2 + \mu mgx$ $F = \frac{kx}{2} + \mu mg$

$F = \frac{2\mu mg}{2} + \mu mg$

$F = 2\mu mg$



Compression in spring for which block can ~~lift~~ lift up.



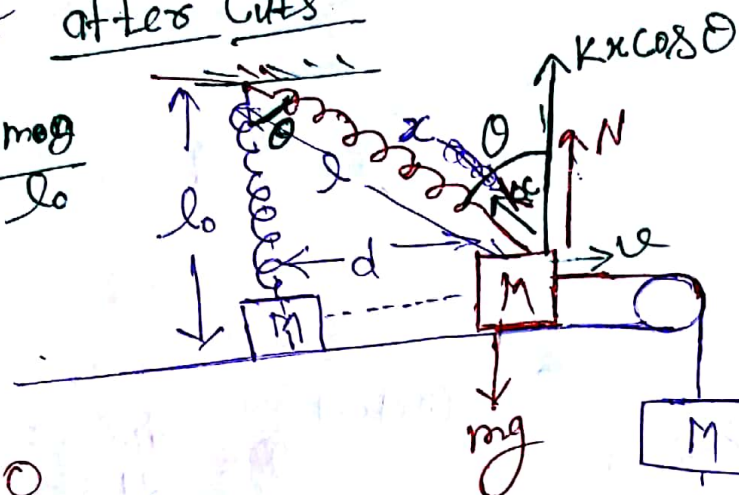
find speed of block A when block B leaving contact after cuts string.

Solve (i) $kx = 2x(m_1 + m_2)g$
 $x = \frac{2(m_1 + m_2)g}{k}$

$x = \frac{2(m_1 + m_2)g}{k}$

3) Solve after Cuts

$$K = \frac{5mg}{l_0}$$



$$x = l - l_0 \quad | \quad d = l_0 \tan \theta$$

$$x = l_0 \sec \theta - l_0$$

$$x \Rightarrow l_0 (\sec \theta - 1)$$

$$l_0 \left(\frac{5}{4} - 1 \right)$$

$$x = l_0 / 4$$

$$N = 0$$

$$mg - Kx \cos \theta = 0$$

$$mg = Kx \cos \theta$$

$$mg = \frac{5mg}{l_0} \times l_0 (\sec \theta - 1) \cos \theta$$

$$1 = 5 (1 - \cos \theta)$$

$$\frac{1}{5} = 1 - \cos \theta \quad \cos \theta = \frac{4}{5}$$

$$\sin \theta = \frac{3}{5} \quad \sin \theta = \frac{3}{5}$$

$$\tan \theta = \frac{3}{4}$$

Velocity of Block A

$$mg d = \frac{1}{2} m v^2 + \frac{1}{2} m v^2 + \frac{1}{2} K x^2$$

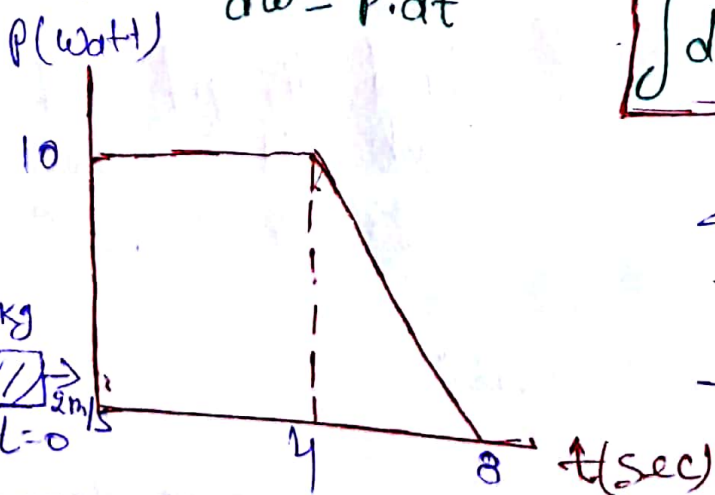
Power

Rate of work done

$$P = \frac{dW}{dt} \quad \left(\frac{J}{s} \right) \text{ (Watt)}$$

$$dW = P \cdot dt$$

$$\int dW = \int P dt$$



$$\Delta K = \frac{1}{2} (8+4) \times 10$$

$$\frac{1}{mg} m (v^2 - u^2) = 60$$

$$\frac{1}{2} \times 2 (v^2 - 2^2) = 60$$

$$v^2 = 64$$

$$v = 8 \text{ m/s}$$

Q=)

P (watt)

6

Find speed @ 8 meter

8 kg



$t=0$

Q=)

$$\Delta K = \frac{1}{2} m (v^2 - u^2) = \frac{1}{2} \times 8 (8^2 - 2^2) = 240 \text{ J}$$

$$P = \frac{dW}{dt}$$

$$= \vec{F} \cdot \frac{d\vec{s}}{dt}$$

$$P = \vec{F} \cdot \vec{v}$$

$$P = F \cdot v \cos \theta \quad \theta = 0$$

$$P = F \cdot v$$

$$P = m a \cdot v$$

$$= m \frac{dv}{dt} \cdot v \cdot \frac{ds}{ds} \Rightarrow m v \cdot dv$$

$$P \cdot ds = m v \cdot v \cdot dv$$

$$\int P \cdot ds = \int m v^2 dv$$

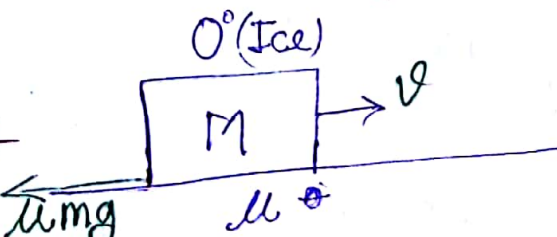
$$\Rightarrow \frac{1}{3} m (v^3 - u^3) = \frac{1}{3} \times 8 (8^3 - 2^3) = 240$$

Efficiency $\eta_{\%} = \frac{\text{Output Power}}{\text{Input Power}} \times 100$

$P = f(t)$ Average power = $\frac{\int P dt}{\int dt}$

Q=)

$L \rightarrow$ Latent Heat



Find distance after which its mass become 50 %

$$\text{Power} = F v \cos \theta = \mu m g v \cos 180^\circ$$

$$\frac{d\theta}{dt} = -\mu mg \quad \Rightarrow \quad L \frac{dm}{dt} = -\mu mg \frac{ds}{dt}$$

$$L \int_{m/2}^{m} \frac{dm}{m} = -\mu mg \int_0^s ds$$

$$L \ln\left(\frac{m}{m/2}\right) = -\mu g s \quad \left(m' = m e^{-(\mu g/L)s}\right)$$

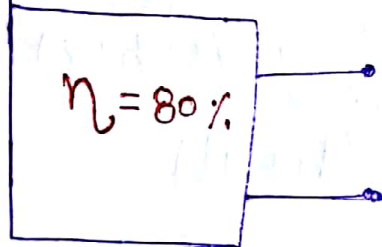
$$s = \frac{L}{\mu g} \ln(2)$$

Q. Wind $\rightarrow$ (Radius) $r = 2m$

$v = 36 \text{ km/hr}$

density of air

$$\rho = 1.3 \text{ kg/m}^3$$



$$P_{out} = \eta (P_{in})$$

$$\Rightarrow \frac{4}{5} \times \frac{dK}{dt}$$

$$\Rightarrow \frac{4}{5} \times \frac{1}{2} \left(\frac{dm}{dt}\right) v^2$$

$$\Rightarrow \frac{4}{5} \times \frac{1}{2} \left(A \frac{d\ell}{dt} \rho\right) v^2$$

$$P_{out} = \frac{4}{5} \times \frac{1}{2} (A \rho v^3)$$

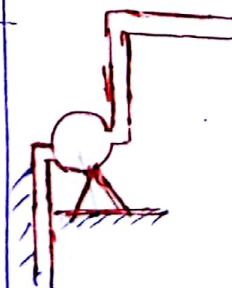
$$P = ?$$

$$= \frac{4}{5} \times \frac{1}{2} (\pi r^2 \rho v^3)$$

$$= \frac{4}{5} \times \frac{1}{2} (\pi \times 4 \times 1.3)$$

KW.

Volume flow Rate	Volume flow rate
Velocity = v	$v' = n v$
force on wall = F	$F' = n^2 F$
Pressure of pump = p	$p' = n^3 p$



Solve: ① $Q = A \frac{d\ell}{dt} = A \cdot v$

$$Q' = nQ$$

$$A' v' = n A v$$

$$v' = n v$$

② $F = A \rho v^2$

$$F' = A \rho (v')^2$$

$$F' = n^2 A \rho v^2$$

$$F' = n^2 F$$

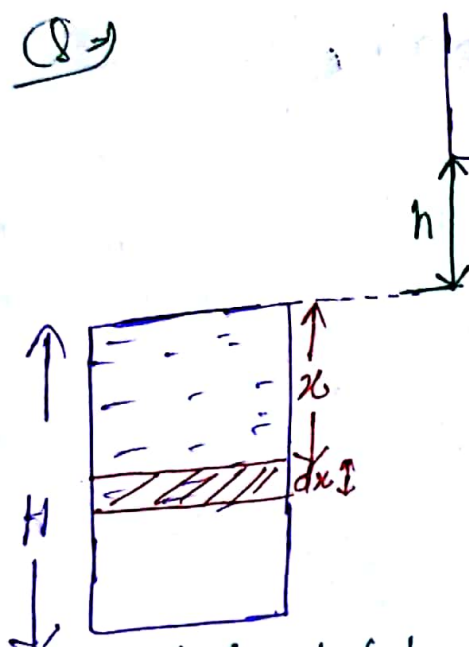
$$p = F' v'$$

$$p' = n^2 F \cdot n v$$

$$\Rightarrow n^3 p$$

$$p' = n^3 p$$

Q=



Large Container

Due to work by external agent level of liquid decreases at Const. rate and become empty after time t_0 , then used Power by external Source at time t .

mass of liquid of density ρ in Container

Rate $a = H/t_0$ after time t

$(dm = \frac{M}{H} dx)$ mass of liquid of layer dx

work done in time $dt = dm \cdot g \cdot (h+x)$

$$dW = \frac{M}{H} g dx (h+x)$$

$$P = \frac{dW}{dt} = \frac{M}{H} g \frac{dx}{dt} (h+at)$$

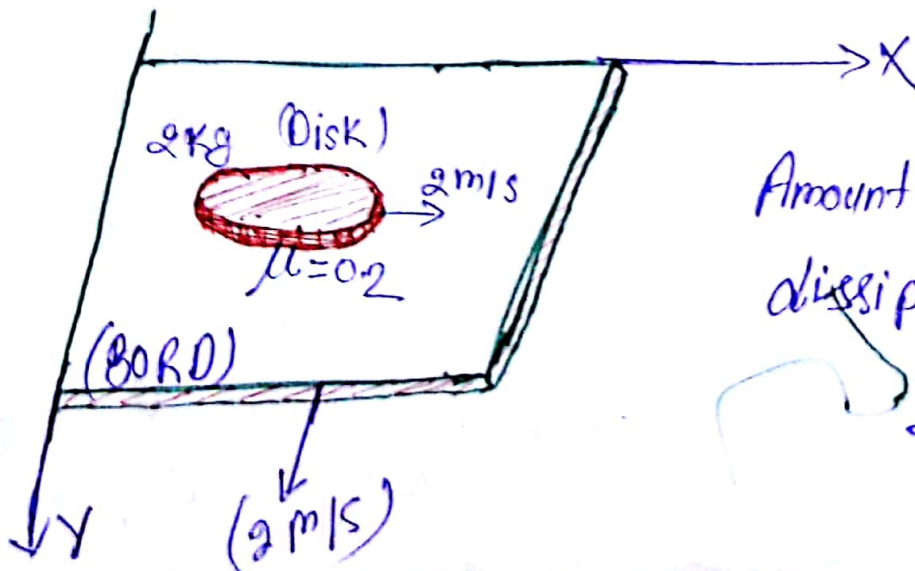
$$= \frac{M}{H} \times \frac{H}{t_0} \left(h + \frac{H}{t_0} t \right) g$$

$$P = \frac{Mg}{t_0} \left(h + \frac{H}{t_0} t \right)$$

Rate $a = \text{Const}$

$$\frac{x}{t} = \frac{dx}{dt} = \frac{H}{t_0} = a$$

Q=



Amount of Heat dissipated per sec.

$$\vec{v}_{0/B} = 2\hat{i} - 2\hat{j}$$

$$\vec{f}_{B/O} = \mu mg \hat{v}_{0/B}$$

$$= 4 \times \left(\frac{2\hat{i} - 2\hat{j}}{2\sqrt{2}} \right)$$

$$\vec{f}_{B/O} = 2\sqrt{2}(\hat{i} - \hat{j})$$

$$\vec{F}_{\text{ext on Board}} = -\vec{f}_{B/O} = 2\sqrt{2}(\hat{j} - \hat{i})$$

Power used by external

$$= \vec{F}_{\text{ext}} \cdot \vec{v}_B$$

$$= 2\sqrt{2}(\hat{j} - \hat{i}) \cdot 2\hat{j}$$

$$= 4\sqrt{2} \text{ watt.}$$

$$\vec{f}_{O/B} = 2\sqrt{2}(\hat{j} - \hat{i}) \quad \vec{F}_{\text{ext}} = 2\sqrt{2}(\hat{j} - \hat{i})$$

$$\vec{v}_{O/B} = 2\hat{i} - 2\hat{j}$$

$$P_{\text{ext}} = \vec{F}_{\text{ext}} \cdot \vec{v}_{\text{ext}} = 8\sqrt{2} \text{ watt.}$$

$$\text{Total used power} = 8\sqrt{2} + 4\sqrt{2} \Rightarrow 12\sqrt{2} \text{ watt}$$

Q $\Rightarrow$ PPF =

2



1 m/s^2

3kg

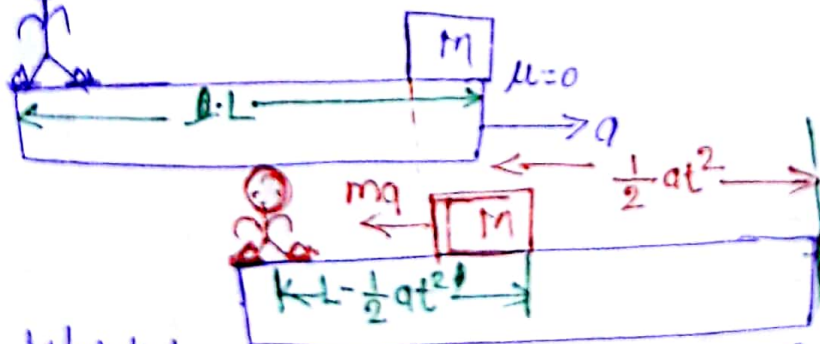
$a_{2/1} = 2 \text{ m/s}^2$

4kg

$a_{1/E} = 3 \text{ m/s}^2$

Work done by block (2) for observer in 2 sec.

O₁



Work done by block in time t for O₂ $\rightarrow$ W_O

O₁ $\rightarrow$ W_{Pseudo force} $\neq 0$

~~Work done by block in time t for O₁~~

$$W_{\text{pseudo}} = \vec{F}_p \cdot \vec{S}_{\text{rel}} = [M_{\text{body}} (-\vec{a}_{\text{observer}})] \cdot \vec{S}_{\text{rel}}$$

$$\vec{F}_p = m(-a\hat{i})$$

$$= -ma\hat{i}$$

$$S_{\text{rel}} = \vec{S}_{B/m} = \frac{1}{2}(\vec{a}_B - \vec{a}_m)t^2 = \frac{1}{2}(0 - a\hat{i})t^2$$

$$S_{\text{rel}} \Rightarrow -\frac{1}{2}at^2\hat{i}$$

$$W = +\frac{1}{2}ma^2t^2$$

~~Imp~~ In above Question

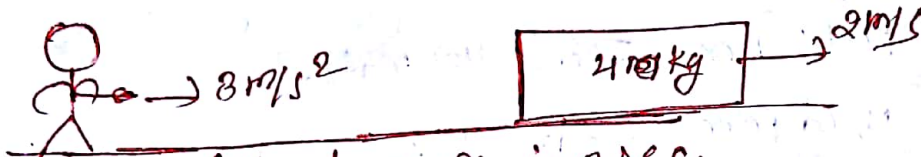
$$\vec{F}_p = 3(-\hat{i}) = -3\hat{i} (N)$$

$$\vec{s}_{rel} = \frac{1}{2} (\vec{a}_0 - \vec{a}_m) t^2 \Rightarrow \frac{1}{2} (\vec{a}_{2/E} + \vec{a}_{1/E} - \vec{a}_m) t^2$$

$$\underline{\vec{s}_{rel}} = \frac{1}{2} (5\hat{i} - 1\hat{i}) \times 2^2 = 4\hat{i} (m)$$

$$W = -24 \text{ (Joule)}$$

Q $\Rightarrow$



Work done by block for observer in 2 sec.

$$\vec{F}_p \Rightarrow -12\hat{i}$$

$$\vec{s}_{rel} = \vec{u}_{rel} t + \frac{1}{2} (a_{rel}) t^2$$

$$= (2\hat{i} - 0) \times 2 + \frac{1}{2} (0 - 3\hat{i}) \times 2^2$$

$$W = \vec{F}_p \cdot \vec{s}_{rel} = -24 \text{ (J)}$$